

DATA PREPARATION AND METHODS FOR ASSESSING U.S. TRANSIT RIDERSHIP TRENDS

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DATA PREPARATION AND METHODS FOR ASSESSING U.S. TRANSIT RIDERSHIP TRENDS

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LIST OF SYMBOLS AND ABBREVIATIONS

ACS	American Community Survey
APTA	American Public Transportation Association
BART	Bay Area Rapid Transit
BRT	Bus Rapid Transit
CBSA	Core-Based Statistical Area
COTA	Central Ohio Transit Authority
DART	Dallas Area Rapid Transit
FTA	Federal Transit Administration
HART	Hillsborough Area Regional Transit Authority
MARTA	Metropolitan Atlanta Rapid Transit Authority
MB	Motor Bus
MBTA	Massachusetts Bay Transportation Authority
MSA	Metropolitan Statistical Area
MTA	Maryland Transit Administration
NFC	Near Field Communication
NTD	National Transit Database
OTP	On-Time Performance
PAAC	Port Authority of Allegheny County
PSTA	Pinellas Suncoast Transit Authority
RTD	Regional Transportation District
SEPTA	Southeastern Pennsylvania Transportation Authority
TCRP	Transit Cooperative Research Project

TNC Transportation Network Company
UA Urbanized Area
UPT Unlinked Passenger Trips
UZA Urbanized Area
VOMS Vehicles Operated in Maximum Service
VRH Vehicle Revenue Hours
VRM Vehicle Revenue Miles

SUMMARY

Public transit ridership in the United States has historically undergone several sustained periods of growth and decline. Since authorities began publishing detailed national data in the 1990s, transit ridership has generally followed a consistent pattern of growth, primarily carried by growth in rail ridership. However, this trend has shifted in the 2010s, with bus ridership beginning a steady decline around 2012 and rail ridership dropping off beginning in 2014. Due to the complex nature of transit ridership, no single cause or set of causes has been fundamentally identified as a contributor to this decline. In addition, the patchwork nature of ridership data from thousands of reporters makes analyzing it in meaningful ways often difficult and time-consuming. In this thesis, I explore various methods of analyzing ridership data for quantifying and identifying key trends in American transit ridership since 2012.

First, I performed a simple peer analysis by grouping agencies with similar modes and ridership, in a manner accessible to agencies. A group was formed around the Metropolitan Atlanta Rapid Transit Authority (MARTA) using ridership data from the national transit database (NTD), which largely matched MARTA's self-generated list of peer agencies. I split modes into dedicated and mixed right-of-way and analyzed them separately for the purposes of describing two separate trends. I then visualized time-series trends in ridership and service over time for these agencies to provide insight into a potential link between the two. While these trends showed interesting relationships between service levels and ridership, they revealed a recent disconnect between the two, indicating that further study was necessary to find the causes of recent ridership decline.

A new methodology was then created to group metropolitan areas with similar transit characteristics in an attempt to connect region-level ridership trends with demographic and population data. This method required the conversion of urbanized area-level service, budgetary, and ridership data into metropolitan area-level statistics. I developed a method to make this conversion on a nationwide level, allowing census data to be integrated into transit data for statistical analysis for the first time. This method gathered all transit agencies operating in a region into one collective group, which then allowed a cluster analysis of these regions. With this cluster method, new peer groups were formed between regions, informing a new set of peers for agencies to look to for benchmarking.

However, regional and nationwide trends were not providing a level of detail necessary to view the complexities of recent ridership changes. Therefore, cluster groups were used to select specific agencies with particularly interesting trends, many which have undertaken innovative treatments on a route or corridor. I analyzed trends in these agencies' ridership in conjunction with service, speed, and reliability since 2012 to provide a more detailed look at ridership change. I then conducted interviews with staff at select agencies with particularly interesting strategies to get an idea of the detailed changes they have witnessed in their ridership. This final analysis provided a more refined look at what agencies are doing on the ground to slow and reverse ridership decline. Overall, I explored the preparation and analysis of data at three levels: agency, peer group, and metropolitan area. Each of these provides important insight to transit ridership at various levels, which will help parse upcoming changes as transit ridership continues to be influenced by a growing number of factors every year.

CHAPTER 1. INTRODUCTION

Ridership of public transit is arguably the most vital metric in the transit industry. It is regularly used to rank and compare cities, regions, and the transit agencies serving them. High transit ridership is often associated with a productive and efficient network, but a wide variety of factors are at play, from economic, to geographic, to political. Growing ridership can indicate a simple increase in service hours, or a shift in a region's priorities. Untangling each of these contributors can be a daunting task, but it is key to sustainable growth within an agency and a region.

1.1 Transit Data Sources

Transit ridership was historically collected and retained for individual agency use, and was never reported on a nationwide scale until 1965. That year, the American Public Transportation Association (APTA) released its first annual report, summarizing ridership across the United States by mode for member agencies (APTA, 1965). This process continues to this day, but additional data sources have since emerged. The most comprehensive resource by far is the Federal Transit Administration (FTA)'s National Transit Database (NTD). A 1974 act required transit agencies to report a wide variety of operating, ridership, and revenue statistics in order to remain eligible for federal funding (FTA, 2018). When the internet became more ubiquitous, these statistics became publicly reported online in the form of the NTD. Since about 1997, the NTD has been the primary source of aggregated transit data in the US.

The NTD provides a variety of resources surrounding transit data. Reports for each agency summarizing ridership by mode, operating statistics, funding sources and expenditures are published annually. In addition, NTD publishes databases of a wide variety of individual statistics across agencies. Most vital to this thesis, however, is the monthly adjusted database, which provides time-series monthly data for each agency and mode going back as far as 2002 or before. The highlighted statistics in the adjusted database include ridership in the form of unlinked passenger trips (UPT), which represent individual segments of a particular trip. In other words, a train-to-bus transfer counts as two unlinked passenger trips. The adjusted database also includes service level data in the form of vehicle revenue miles (VRM) and vehicle revenue hours (VRH) and fleet size in the form of vehicles operated in maximum service (VOMS). This database is particularly useful in the examinations of trends across time, as both ridership and service data exist in the same place, in the same format, for the same agencies and modes, across nearly two decades. Despite the immense value of these resources, there are several drawbacks to the structure and availability of both NTD and APTA data which has a significant bearing on the depth of possible analyses. These limitations are discussed further in Chapter 3.

1.2 Historic Ridership Trends

Transit ridership in the last century has gone through several distinct periods. In the early 20th century, transit boomed as technology allowed for the construction of streetcars and subways that beat out walking travel times by a dramatic margin. Post-World War II, the US began shifting in a number of ways that were not to transit's favor. Federal highway systems and cultural changes pushed automobiles to quickly outpace transit vehicles, which in turn allowed for increased suburbanization of formerly dense cities that were well-

served by transit. Following several decades of ridership decline, the oil crisis of the 1970s prompted some systems' increasing ridership and investments in rail systems. Starting in the 1990s, time-series data for rail and bus modes became available from APTA, and this data is shown in Figure 1. Viewing this ridership data over time shows various cycles of small ups and downs over the past three decades, but a generally positive trend in rail ridership accompanied by a generally flat trend in bus ridership. Total ridership grew by nearly 17% between 1990 and 2015, and over 30% between a low point in 1996 and 2015.

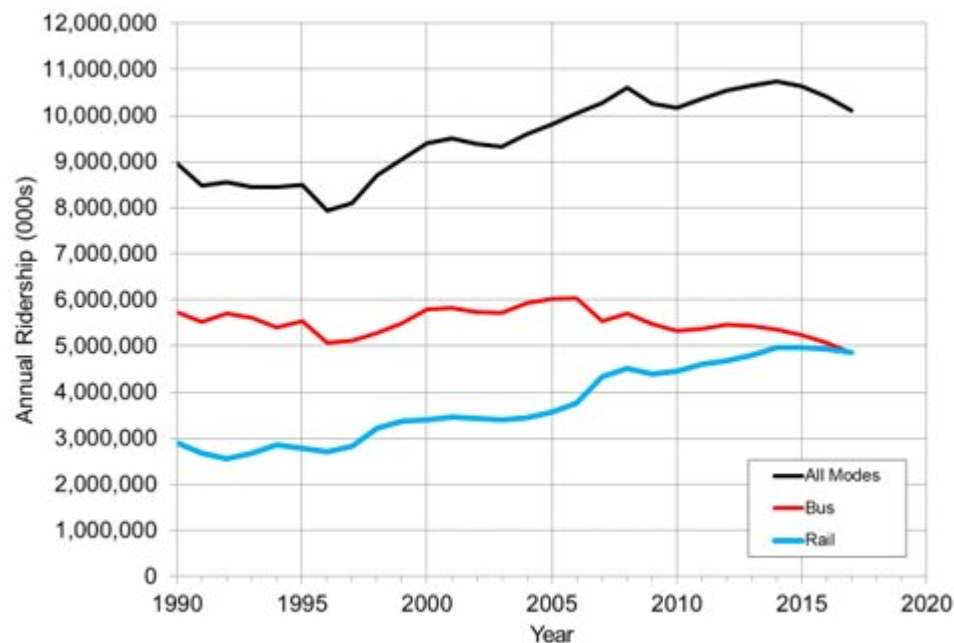


Figure 1 - National Ridership Trends Since 1990, Credit: Dr. Simon Berrebi

On the right side of Figure 1, there is a noticeable downward trend in bus ridership beginning around 2012, and a similar trend for rail ridership beginning around 2014. While at first appearing rather small in the context of the past three decades, this trend is made more worrisome by two factors. First, the total population has grown nearly 4% since 2012 and nearly 30% since 1990. This means that ridership growth per capita is substantially

less than total growth, and also that bus ridership per capita has generally been declining since 1990 and has recently begun to sharply fall off. Second, the the U.S. economy has generally improved since 2012, which is usually associated with ridership growth. Stagnation and decline are generally not expected under these circumstances, and yet Americans are witnessing the longest period of sustained loss in transit ridership since 1990. These trends are particularly concerning, as annual bus ridership drops below 5 million, because there is evidence that it is at its lowest point since APTA records became available in 1965 (APTA, 1965).

1.3 Motivation and Research Design

Because of these recent declines, many researchers and practitioners in the transit industry are looking for answers. Some are pointing fingers at TNCs, whose low prices and convenience have the potential to pull riders off of transit, while some believe that demographic changes are at play. As these theories begin to be tested with recent ridership data, it can be difficult to grasp how to correctly approach the issue. Nationwide trends are often displayed with worrisome messages, but these aggregated changes can be misleading. For instance, the New York City region accounts for just over half of the ridership in the entire United States. When there is a ridership crisis in New York, the entire country's trends reflect this. Meanwhile, a city across the country could be experiencing ballooning ridership with little press.

This thesis seeks to provide a variety of tools with which to approach transit ridership change. Data preparation and quality assurance can be just as crucial to the results as the level of analysis and aggregation. Through three separate studies, I explored three

different data preparation procedures at three different geographic levels. These three methods were each developed to serve different goals. First, to inform a specific agency on their performance in the context of their peer agencies. Next, to view transit data at a metropolitan area level, to then be used in further study clustering these regions into peers. And finally, to examine short-term effects of specific projects that agencies have undertaken to improve on recent national declines. These methods can not only be used to inform future analysis of transit data, but also to unravel different factors affecting transit ridership at various levels of space and time.

The following chapters are laid out so as to paint a complete picture of factors affecting transit ridership, the data available to researchers, and methods for aggregating and viewing this data. Chapter 2 presents a review of literature relevant to transit ridership. This includes large-scale studies modeling ridership over time and space to a variety of factors, as well as surveys and case studies from the past several years which attempt to document and explain recent declines. Chapter 3 then describes limitations of the available data for both transit and demographic statistics, and what this may mean for those studying ridership. In Chapter 4, I discuss an analysis of peer transit agencies, and variations in trends for service and ridership across these peers. Chapter 5 is also about peer analysis, though looking from a regional perspective rather than at the agency level. I discuss my methods of data aggregation to allow for the integration of census data, as well as the results of a study conducted as a result of this integration. Finally, in Chapter 6, I look at ten case study agencies of varying sizes that have made innovative attempts to combat ridership decline. I aggregate their data and document recent changes in their ridership, service, and reliability to show the effects of these changes. Through all of these sections, I attempt to

parse the various trends taking place at different levels of analysis, and how these relate to literature on the subject as well as areas where additional data and research are needed to form further conclusions about ridership change.

CHAPTER 2. LITERATURE REVIEW

In order to understand recent ridership trends in context, a thorough review of a variety of academic and industry sources surrounding transit ridership both overall and within the past several years was conducted. Included in this literature review are studies investigating historical transit ridership effects, studies exploring specific policy changes and associated ridership effects, and studies comparing various regions and transit agencies.

The approach was to first look to national studies on transit ridership both recently and in the past. These studies tend to look at ten or more metropolitan areas in North America to highlight the trends associated with ridership overall. Then studies on specific factors such as density or presence of transportation network companies (TNCs) were reviewed. These studies tended to focus on case studies or surveys sent to riders to summarize the impacts of a specific aspect or set of aspect that affects transit ridership. Finally, to get a sense of the efforts of agencies to bring back riders in recent years, news articles and agency reports on specific efforts, their public perception, and early results were reviewed. This method unveiled a holistic view of transit ridership, recent trends, and what is being done to combat them.

What follows is first an overarching summary of trends identified in the literature. This is a large-scale view that attempts to seek an answer to the factors driving transit ridership in general and those responsible for recent declines. Following the summary section, a thorough review of relevant literature is presented in full.

2.1 Overarching Trends

Based on a review of the literature described above, several overarching trends have been identified and are presented below.

- **In nationwide studies, the most vital factor affecting ridership is the amount of service provided.** Historically, ridership and service (such as vehicle revenue miles or hours) are highly correlated at every level of transit service. Agencies that increase service tend to see corresponding ridership increases. This service may be in the form of a new area served by transit or simply more frequent service to existing areas.
- **However, in the past few years, many agencies have increased service without associated ridership increases.** Contrary to historic trends, agencies have not seen the ridership gains from service improvements that they had seen prior to 2008.
- **Transit ridership is cyclical and tied to economic factors.** Unemployment and to a lesser extent gas prices affect transit ridership nationwide, and while low unemployment creates more trips, it also increases vehicle miles and purchases. Since about 2012, the economy has improved, likely playing a role in ridership declines.
- **Ridership is also tied to built environment factors.** Higher housing and employment density correlate to higher transit ridership, and higher availability of parking at workplaces has been shown to decrease ridership nationwide.
- **Shifts in housing and demographics are not favoring transit access.** Despite a brief trend in the other direction, suburbs are outpacing urban cores in growth nationwide. These fast-growing suburbs are generally not as accessible by transit as urban cores. Additionally, gentrification in urban cores has displaced transit-

dependent populations to suburbs, and wealthier groups who are less likely to take transit have been taking their place.

- **There are a growing number of resources that replace the need to make trips.** Telecommuting and working from home are trends that have grown considerably in recent years, driving down the need for monthly transit passes. Delivery services such as Amazon or GrubHub make trips to stores and restaurants less necessary and frequent, and are particularly prevalent in urban areas well served by transit.
- **Shared mobility services are growing in popularity and likely have mixed effects on ridership.** Bike and carsharing services make auto ownership less necessary, but there is evidence that they may be replacing transit trips. Transit agencies and city officials are largely skeptical of integration with these services, as they see them as competitors.
- **There is evidence that Uber and Lyft replace transit trips, particularly outside of peak hours.** TNCs like Uber and Lyft are used primarily for recreational purposes rather than commuting, and many users report that these services replaced their transit trips. Overall, TNCs likely add auto trips to the road, and raise vehicle miles traveled.
- **There is also evidence that Uber and Lyft complement transit, particularly for rail systems.** TNCs have the potential to serve as last-mile connections to rail and bus systems, and many cities have begun supplementing their demand-responsive service with TNC services to bridge system gaps.
- **Transit agencies have been upgrading technology in an attempt to win back riders.** Improvements in real-time information has been shown to boost ridership slightly. Fare technology that improves simplicity and speeds up buses is being

implemented in several cities, with limited results on the ridership effects of these changes.

- **Bus networks are being restructured to provide more concentrated service and attract riders.** This trend consolidates low-frequency meandering services into high-frequency direct services, bringing more residents closer to high-frequency bus lines. Ridership effects have been slightly positive, but with limited results at this point.
- **Overall, there is little consensus as to the full picture describing recent ridership declines.** There are a multitude of candidate factors, from competing services like Uber to societal factors like gentrification. The most likely answer is that each city and region is experiencing a unique combination of all the factors mentioned above. Transit agencies are facing a unique set of challenges to retain and gain back riders.

2.2 Full Literature Review

The Fourth Quarter 2016 APTA ridership report showed an overall decline of 2.30% in passenger boardings for the year and 4.29% for that quarter across all modes. In 2017, following five years of consecutive decline, bus ridership attained its lowest point since at least 1990, which is the oldest ridership data available from APTA. Even heavy rail began declining following an upward trend since 2009. There are many possible factors for this decline in ridership. A recent APTA report identified erosion of time competitiveness, reduced affinity, erosion of cost competitiveness, and external factors as major trends in transit ridership (APTA 2018). While these trends are clearly happening, transit agencies need to understand the problem more specifically to address the underlying

causes of transit ridership. What follows is a review of the literature on the factors found to affect ridership in recent years. While this review provides important leads, the literature has not yet painted a full picture of the forces pulling transit ridership downwards.

Despite some trends that were temporarily going in the opposite direction, suburbs have outpaced urban cores in growth rate (Frey, 2018). At the same time, many trip purposes are disappearing. According to a 2016 Gallup poll, 43% of Americans reported working remotely at least sometimes, a 4-percentage point increase since 2012 (Gallup 2017). Telecommuters also reported working remotely more often; 75% reported working from home more than once a week from 66% in 2012. Additionally, delivery services such as Amazon and GrubHub have made shopping and dining delivery possible (Suel et al. 2018). However, total vehicle miles traveled are now at their highest point in history (Davis, 2017). This indicates some complex changes in travel behavior that are shifting transit riders to automobile travel.

Many in the industry are quick to blame these declines on Transportation Network Companies (TNCs) such as Uber and Lyft, which have used real-time and location-aware capabilities of smartphones to provide on-demand and/or tailored travel options to customers. These ride-hailing services have put dispatching and cashless payment options in the hands of the riders, proving strong competition to traditional transit services. Others believe that the decreases in transit ridership are due in part to the increases in bicycling and walking as modes of transportation with bikeshare programs claiming much of the decrease in transit ridership.

In an attempt to turn the declining ridership trend around, transit agencies have implemented new strategies, described below. New fare technologies are helping to reduce the friction in transit fare purchasing. Transit agencies are also redesigning their bus network to increase frequencies on their core routes and attract new riders. Transit agencies are implementing micro-transit pilots to provide a similar experience to TNCs. These strategies attempt to work in opposition to factors which negatively impact ridership, both traditional and emerging.

2.2.1 Traditional causes of transit ridership increase and declines

Many factors affecting transit ridership are well established within the literature, and well summarized in Taylor and Camille (2003). Transit ridership is cyclical in nature and is substantially impacted by the economy and population changes, such residential location choices. The level of employment has a mixed effect on ridership, while greater employment generates more trips from commuting and consuming, they also lead to private vehicle purchase (Hendrickson, 1986; Liu, 1993). The overall effect of employment, however, has been found to be positive overall on ridership (Gomez-Ibanez, 1996). While gas prices have been found to have little impact on transit ridership, parking availability is an important determinant (Sale, 1976; Dueker, 1998). Transit ridership is highly correlated to housing and workplace density, although this variable has a relationship with many other ridership factors (Pushkarev and Zupan, 1977; Spillar and Rutherford 1998; TCRP Report 95, 2004). Although sensitivity to fare can vary widely within the customer base, modest changes in fares have been found to greatly affect ridership (Liu, 1993; Kohn, 2000).

2.2.1.1 Service Levels

There is a consensus in the literature that the primordial factor for transit ridership is the service levels. In a simple one-variable regression of 265 urban areas, Taylor et al. (2009) found that vehicle revenue hours explained 95% of the variation in ridership. Dill et al. (2013) used bus stop-level data to model the determinants of transit ridership in three metropolitan regions in Oregon: Portland, Eugene, and Rogue Valley. They found that level of service characteristics were the most important factors to determine ridership. In Portland, where levels of service characteristics explained 41% of the variance in ridership, each extra minute of headway was associated with a four to five percent drop in ridership.

Service levels are not just good prediction variables for modeling transit ridership; their fluctuation also affects changes in ridership over time. In a 1988 time-series study, Kyte et al (1988) compared transit ridership over several operators in the region of Portland, OR, before and after service changes. They found that ridership elasticity to service hours varied considerably among routes, but that the average significant elasticity was 1.34. Kain and Liu (1999) evaluated the factor that contributed to increasing ridership in Houston and San Diego in the late 1990's, while transit ridership was declining across the United States. The authors concluded that the increases in service, reduction in fare, and growth in employment and population contributed the most to increasing ridership. More recently, a study by Boisjoly et Al. identified Vehicle Revenue Kilometers as the primary determinant of ridership in a panel regression study of 25 transit agencies from 2002 to 2015. A multitude of further studies have also confirmed the strong correlation between ridership vehicle revenue miles and vehicle revenue hours (Liu, 1993; Gomez-Ibanez, 1996; Kohn, 2000; TCRP Report 95 2004).

2.2.2 *Factors impacting recent changes in transit ridership*

Recent shifts have introduced new alternatives to transit that may play a role in declining ridership. Although competition from other modes has always been prevalent, new modes such as TNCs, bikeshare and carshare are providing new options for travelers and new competition for transit. Furthermore, changes to how people travel are impacting ridership as well. Telework, flex work schedules, and online shopping are becoming more prevalent and impacting the demand for travel or the times we do it. In addition to shared mobility, three of the major factors impacting transit ridership are described below: demographic shifts and workplace policies.

2.2.2.1 Demographic Shifts

Income, age, and race demographics are strongly correlated with car ownership, which is one of the main determinants of mode choice. Taylor et al. (2009) found that the population of recent immigrants, and the percent of carless households were positively correlated with transit ridership. The correlation between demographic characteristics and transit ridership remains strong even when taking population density and access to transit into consideration. Owen and Levin (2015) predicted mode share based on accessibility measures and on demographics using data from the Minneapolis-Saint Paul Metropolitan Area at the census block-group level. They found that transit mode was negatively correlated with income and vehicle ownership, even when considering accessibility. Driscoll et al. (2018) modeled the impact of population age on transit ridership since 1989. They found that a contributing factor to the decline in ridership per capita was an aging population that makes less trips on average. In addition, the authors point to slower rates

of population growth in US counties with abundant transit service than in counties with little transit available.

A potential contributing factor to the decreasing transit ridership is therefore the economic displacement of low-income earners from dense urban-centers to the suburbs. In his book, *The New Urban Crisis*, Richard Florida describes the phenomenon of gentrification taking place in major American metropolitan areas (Florida, 2017). While cities are becoming denser, their populations are becoming whiter, have higher-incomes, and more cars. A study from Tri-Met staff in Portland, OR, identified low-income migration as a major factor of transit ridership decline (Mills and Steele, 2017). The study compared bus stop-level changes in the real-estate values with ridership changes and found a significant overlap. These preliminary results suggest that focusing service entirely on highest-density areas may not yield the maximum ridership.

In a 2018 report for the Southern California Association of Governments, increasing auto ownership especially among lower-income households was found to have a significant effect on falling transit ridership in the Southern California region (Manville et al., 2018). The region, despite heavy investments in transit infrastructure and service levels over the last 30 years, saw some of the largest drops in ridership, nearly 72 million annual trips, between 2012 and 2016. The study claims that most of the regions' ridership comes from a small proportion of people and neighborhoods, and despite investigating fares, fuel prices, TNCs, and displacement, vehicle ownership was found to play a dominating role in ridership drops according to their model. These findings are largely limited to the Southern California region, which may vary from the rest of the country in a variety of key factors surrounding vehicle ownership and use.

2.2.2.2 Workplace Policies

Workplace policies have evolved in ways that may affect fare purchases and transit ridership. The proportion of the population working from home has increased by 10% in the last decade. This trend may affect commuters' decisions to purchase monthly passes in favor of more flexible options. A study from Habib (2017) indicates that owning a transit pass correlates negatively with high-frequency telecommuting. The study, however, focused solely on post-secondary students in Toronto. More research on this phenomenon is needed to help transit agencies develop fare policies that support ridership.

Workplace policies have also been shown to alter employees' commuting habits in more general ways. A 2017 study by Bueno et al. used a multinomial logit model to show that parking and driver mileage benefits correlated with decreased transit use, while transit benefits and discounted passes correlated with higher transit use. This study was limited to New York and New Jersey, states with historically high transit use per capita. Similar research was conducted by Dong et al. (2016) in Portland, OR, and Block-Schachter & Attanucci (2008) in Boston, both with similar results. There is limited research on transit benefit programs in small urban areas with a lower transit mode share.

2.2.2.3 Ridership effects of Shared Mobility

The impact of new mobility services on traditional transit has been the subject of much speculation. Some see these new services as competitors that simply skim choice riders from the transit system, while others believe that offering as many mobility options as possible enables individuals to choose a car-free or car-lite life. There are many opportunities where public transit and technology-enabled transportation service providers

can work together - services can fill transit service gaps, serve last mile connections, be more cost-effective for serving seniors and those with disabilities, and provide support during emergencies. Understanding why customers choose these mobility options can help provide first-hand information about the pros and cons of these services. Gathering information about the kind of trips these individuals make can further provide insight into the relationship between these services and traditional transit.

Two recent papers have studied the relationship between TNCs and transit using regression models. A large study on transit ridership by Boisjoly et al. (2018) used data from the 25 largest transit agencies in North America. The study measured the presence of Uber as a binary variable using the opening dates from a review of press releases. This study found that the presence of Uber did not have a statistically significant correlation with increased ridership. Most of the variation in ridership comes from the amount of service provided by each agency. A study by Hall et al. (2018) employed a difference in differences regression to evaluate the relationship between Uber presence and transit ridership. In addition to the binary presence of Uber in a metropolitan statistical area (MSA), the study measured the intensity of search engine searches using Google Trends. The study found that Uber presence and intensity correlated with ridership decrease in MSAs with smaller population sizes and ridership increase in MSAs with large population sizes.

In a Center for Urban Transportation Research report (2016), Steve Polzin outlines policies for public transportation with regard to TNCs (and automated vehicles). He advises that agencies monitor the impact of technology on travel behavior, redefine transit's role

as mobility options change, and position transit to address emerging issues. He specifically addresses the possibility of evolving paratransit and affordable mobility.

A Transit Center report published in early 2016 suggested that transit agencies partner with TNCs to create efficiencies in how service is provided by replacing inefficient markets and reallocating services (Transit Center, 2016). They also suggested that transit agencies prompt TNCs to exchange data to understand rider needs better and many agencies have been following this advice. The result of this agency push to exchange data resulted in Uber opening up some usage data for analysts to begin to dissect.

In a chapter of Meyer and Shaheen's *Disrupting Mobility*, Henao and Marshall (2017) explain the complexities of understanding the impact of TNCs on the transportation system. First, the amount of open data to understand how TNCs are used is limited. Second, it is difficult to assess if a TNC trip is a replacement transit trip or not. Even if a particular trip takes place with a TNC, it may enable a household to own one less car and encourage more usage of transit in general. They employ modality styles (car, multimodal with car, non-car, and bi-style) to classify travelers.

One study conducted in Boston, Chicago, New York, Seattle, and Washington DC used a targeted email survey to understand TNC usage (Clewlow, 2016). The surveys had 2,100 respondents in both urban and suburban transit-served neighborhoods with 426 respondents stating they were carsharing members (20%) and 674 who had used ridehailing (32%). In comparing the two major TNCs, the study found that the Uber market was much stronger with 90 – 97% of adopters having used Uber as opposed to 22 – 31% having used Lyft. A study from the San Francisco County Transportation Authority found that TNC

trips are concentrated during peak hours and in the densest parts of the city (SFCTA, 2017). The study also found that TNCs contribute 6.5% of all VMTs in San Francisco.

Another study conducted by Clewlow and Mishra (2017) used an internet survey to target a wider range of neighborhoods and suburban areas in Boston, Chicago, Los Angeles, New York, San Francisco, Seattle, and Washington DC. The survey collected information on attitudes towards travel, neighborhood, technology, and environment, as well as vehicle ownership and housing choice, and had nearly 4,100 respondents from a wide variety of population and housing densities both urban and suburban. They found that adopters of TNCs reduced their bus usage by 6% but increased their commuter rail usage by 3% on average, and that 22% of respondents reported making a trip with a TNC that they would not have made without it, indicating a rise in overall trips due to TNCs.

Another study conducted in San Francisco used an intercept survey of taxi and ridesourcing customers (Rayle et al, 2016). They found that 33% of rideshare users would have made the trip by transit, 39% by taxi and only 6% would have driven their own car. Comparisons of trip origins and destinations showed that ridesourcing users saved 10 minutes on average with a 22 minute average trip, although some trips would have been shorter on transit. However, the study was conducted among ridesourcing and taxi riders, which would presumably include more people for whom the transit trip was not the best choice.

The most comprehensive work to date on the subject is the Transit Cooperative Research Project (TCRP) Report 188 (Feigon & Murphy, 2016). The study draws on interviews with transportation agencies; a survey of shared mobility users; travel time,

demand, and capacity analysis; an assessment of paratransit practices and regulations; and documentation of business models. “The report presents five key findings:

1. Among survey respondents, greater use of shared modes is associated with greater likelihood to use transit frequently, own fewer cars, and have reduced transportation spending;
2. Shared modes largely complement public transit, enhancing urban mobility;
3. Because shared modes are expected to continue growing in significance, public entities should identify opportunities to engage with them to ensure that benefits are widely and equitably shared;
4. The public sector and private mobility operators are eager to collaborate to improve paratransit using emerging approaches and technology; and
5. A number of business models are emerging that include new forms of public-private partnership for provision of mobility and related information services.” (pg. 6)

In the TCRP study, respondents reported that ridesourcing was used for recreation or social events the most (54%), followed by commute (21%), and shopping / errand (16%). Ridesourcing was the least preferred mode in the early AM, AM rush, and midday, but the most preferred mode in evening and late night. In the survey, 43% of respondents reported using public transit more since shared modes became available, but 28% reported using public transit less. Of the respondents, 20% postponed buying a car, 18% decided not to buy a car, and 21% sold and did not replace a car since starting to use shared modes. However, the survey results were a convenience sample and therefore cannot be applied to

the larger population. The survey also took place only in very large, dense cities including Austin, Boston, Chicago, Los Angeles, San Francisco, Seattle, Washington DC, and New York.

Agencies interviewed for the study expressed a strong desire to form partnerships with ridesourcing companies to bring down the cost of paratransit trips. Several hurdles were identified, however, including drug and alcohol testing of drivers, liability associated with transferring of non-ambulatory passengers, provision of door-to-door rather than curb-to-curb, wheelchair and service animal accommodations, vehicle safety and insurance requirements. Two additional papers found were duplicative of the efforts reported in TCRP Report 188 (Iacobucci, et al, 2017; Shared Use Mobility Center, 2016).

A FiveThirtyEight article looked into the relationship between transit and TNC usage, and cost factors for households with varying levels of transit service (Silver and Fischer-Baum, 2015). Uber usage appeared to correspond well to transit usage in New York City, and neighborhoods with no subway access had significantly fewer Uber trips than those with even one line, suggesting a link between the two. The authors examined cost of vehicle ownership and determined that middle-income groups with at least moderate transit access would save money by relying on a transit-TNC combination. The article did not discuss its methodology or sample size, limiting its authority.

Despite limited research on TNC's relationship to transit ridership, several studies have looked at taxis' effect on transit demand and ridership. Taxis' impact on transit may be similar to that of TNCs, as they both provide an on-demand mobility service with high demand. Nearly all taxi studies involve New York City taxi data, due to its accessibility

and scale. One study by Yang and Gonzales (2014) created a model for estimating taxi demand in New York City based on 147 million taxi trips and the control of several factors. Among them was transit access time (TAT), a measure of access adding the walking time to the nearest station to the expected waiting time, which is calculated has half the scheduled headway. The study found that the increase of TAT by one minute correlated with a reduction in 36 taxi trips, and that as TAT improved, taxi trips rose, indicating a connection between the two. Despite controlling for employment and population density, the authors admitted that some connection may be skewed by the disproportionate amount of taxis and subway lines in lower Manhattan.

A similar study by Wang and Ross (2016) explored the transit-competing and transit-complementing effects of taxis in New York City. Trips from a seven-day sample were categorized as transit extending if they began or ended at a transit station and ran outside of a transit-served area, transit complementing if they served as a substitute for a transit service that was nonexistent or not running at the time, and transit competing if the same route could have been achieved using transit. Binary logit models were run to determine trip types and link them with sociodemographic and built environment factors. The study found that 48% of trips were transit competing, 44.4% were transit complementing, and 7.4% were transit extending. The authors concluded that around half of trips replaced transit trips while the other half complemented transit services. A study in Boston, MA performed a similar analysis to investigate taxis' competing or complementing elements (Austin and Zegras, 2012). The study showed that heavy rail stations generated less trips than surrounding areas, but that the opposite was true for light rail and BRT services.

Another study in New York City ran utility models on taxi and transit trips between New York area airports and Pennsylvania Station (Yang et al., 2014). A binary logit model was used to select mode choice based on utility functions, cost, and travel time valuation. Cost prohibited the utility of taxi trips for all times of day except overnight, when transit service frequency dropped significantly. Transit was most valuable during peak periods, when headways were shortest and vehicular traffic was highest. This study was limited by its evaluation only of New York City, where transit options are abundant and frequent, and where roadway traffic is high.

Several studies on the impact of other forms of shared mobility on transit, including more established forms such as carsharing, have been conducted with mixed results. Households that utilize carsharing have been shown to use transit less than before joining carsharing (Martin and Shaheen, 2011), and zero-car households that utilize carsharing have been shown to use transit less than zero-car households in general (Sioui et al., 2012). A study combining 15 reports, however, described car sharing members' transit usage increase between 13.5 to 54% after joining carsharing (Shaheen, Cohen, Chung, 2009). Variabilities in this reports' results indicate that carsharing members' transit usage varies widely by region, and that the rapidly changing landscape of transportation options has an unpredictable effect on mode choice.

On the whole, research in the area of transit partnerships with TNCs and the impacts of TNCs on transit ridership is severely limited due to the recent emergence of the services. Survey studies such as Clewlow, 2017, help understand the attitudes of transit riders through stated preference. Regression studies such as Hall et al. 2018 and Boisjoly et al. 2018 help establish the connection between the presence of TNCs of transit ridership.

However, neither approach has managed to establish clear trends. There needs to be a study of revealed preference on wide and representative scale in order to observe the full effects of TNCs on transit ridership. However, there is a consensus: understanding the competition and complementarity between transit and TNCs is among the most pressing research needs.

2.2.3 Strategies to increase transit ridership

This therefore begs the question of how agencies should address these factors, including modifying service to accommodate changes in the transportation system. Strategies can be operational in nature, such as route and network restructuring. They can be technological, such as new fare technologies or real-time information. They can involve new service types, such as demand-responsive transit. They can even involve new communication and marketing campaigns. Some of these strategies are discussed below.

2.2.3.1 Fare and Real-time Information Technologies

Recent technological advancements in fare payment technology are making it easier for passengers to use and pay for transit. Two emerging technological trends are occurring simultaneously: app-based smartcard payment systems such as Chicago's Ventra, and Near Field Communication (NFC) payment systems that do not require a transit pass at all as in Salt Lake City. These systems are flexible and save passenger time by avoiding the lengthy process of purchasing physical fare media. Due to the recent emergence of mobile-payment technologies, there still lacks research on their impact on transit ridership. A study by Brakewood, Macfarlane, and Watkins (2015) examined bus ridership changes in New York City in response to the gradual availability of real-time bus information. The

study revealed a median ridership increase of 2.3%, with higher increases on the largest routes.

2.2.3.2 Bus Network Restructuring

Many recent service-related efforts to increase transit ridership have consisted in restructuring bus networks to prioritize service concentration over coverage. In August 2015, Houston's Metropolitan Transit Authority of Harris County redesigned their bus network overnight, increasing high-frequency bus routes, while cutting lower-frequency routes. Omaha Metro Area Transit, Austin's Capital Metro, and Columbus' Central Ohio Transit Authority (COTA) followed suit with their own network redesigns. Seattle's King County Metro went through a similar process albeit over several years (King County Metro, 2017). Metropolitan Atlanta Rapid Transit Authority (MARTA) commissioned a Comprehensive Operations Analysis study, which also recommended concentrating service on core corridors (Parsons Brinckerhoff, 2016). In reducing their coverage, however, MARTA has faced stiff resistance from residents who rely on bus service as their only mode of transportation (Abubey, 2017).

Called the "hottest trend in transit" by Governing Mag at the end of 2017, bus network restructuring is being considered by transit agencies across the nation. The Los Angeles Metro announced in May 2017 the start of a three-year process to restructure the bus network in response to a 20% drop in ridership over three years (Hymon, 2017). The Dallas Area Rapid Transit (Schmitt, 2017), the Southeastern Pennsylvania Transit Authority (Laughlin, 2017), and the Washington Metro Area Transit Authority (Powers, 2017) are planning similar bus network redesigns. Transit agencies are hoping that

concentrating service on core corridors will help increase transit ridership. This expectation is supported by the positive results bus network redesigns have received so far. In November 2017, Streetsblog USA wrote that, “Transit ridership is falling everywhere – but not in cities that redesigned their bus networks” (Schmitt, 2017).

One potential contributing factor, which has not been addressed in the literature or in the press, is that these bus network redesigns were accompanied by net increases in bus operating budgets. In Houston, bus ridership increased by only 1.2% in the first year, which was much lower than the 20% expected, even though the operating budget increased by 4% (Vock, 2017). In Seattle, bus ridership increased by 0.4% between 2014 and 2016, during which King County Metro redesigned their bus network (Small, 2017). During the same period, the transit agency also increased bus-operating budget by 15% and implemented bus prioritization treatments. In Austin, the ridership increase is also partly attributed to night and weekend bus service expansions (Pritchard, 2017).

There is a need for research to parse the contributing factors of ridership and evaluate the singular impact of prioritizing concentration over coverage. A key element that needs to be understood is the notion of access. Low-frequency transit routes can be used as access modes to feed into high-frequency routes. The ridership on high-frequency routes should therefore be categorized by access mode to fully understand the dynamics of ridership and the impact of bus network redesigns.

2.2.3.3 Implementing Demand-Responsive Transit

To provide greater transit access in low-density neighborhoods, a new strategy consists in using demand-responsive transit. Research has shown that in low-density areas,

demand-responsive transit can service short trips faster (Qiu et al. 2015) and at a lower cost than fixed routes (Edwards and Watkins, 2013). Several transit agencies have implemented demand-responsive service either to reach the first-and-last-mile or to connect origins and destinations directly.

There are two main approaches used in practice to provide demand-responsive transit. The first approach consists in using third-party software to dispatch agency operators. The Denver Regional Transit Authority has been providing dynamic rides with their own vehicles and operators since 2000 (Becker et al. 2013). The Kansas City Area Transportation Authority and Santa Clara Valley Transportation Authority both offered demand-responsive transit programs operated by their own staff, but the programs were discontinued due to insufficient ridership (Westervelt et al. 2018). Austin implemented a similar program and reached their six-month ridership goals within two months (Bliss, 2017).

The second approach consists in employing independent drivers who use their own vehicles to pick-up customers at their door. Pinellas Suncoast Transit Authority was the first transit agency to subsidize a portion of Uber, Lyft, and taxi trips to and from their bus stops. The Los Angeles Metro is planning a similar program in partnership with the technology company, VIA. The advantage of going through independent drivers is that the transit agency can take advantage of economies of scale from existing networks of ride-hailing drivers. There still lacks, however, quantitative research to assess the service and ridership implications of the programs.

2.2.3.4 Communication and Marketing

To increase the visibility of transit service, agencies are also looking to improve communication and marketing. Transit marketing has traditionally been eligible for the federal Congestion Mitigation and Air Quality programs in regions that are not attaining air-quality standards. For example, the Atlanta Regional Commission used the funds for a social media campaign to convince people to try transit. In the book, *Best Practices for Transportation Agency Use of Social Media* (2013), Bregman and Watkins describe potential strategies for transit agencies to create an online presence. While the impact of marketing campaigns on transit ridership has been mixed, research has shown that targeted campaigns, especially for expanded service are most effective (TCRP Report 95, 2004). Van Lierop and El-Geneidy 2017 developed a conceptual framework to segment the market for marketing efforts.

2.2.4 *Conclusions*

There are several conflicting trends in the rapidly changing transportation market, and public transit may be falling behind. TNCs have the potential to reduce or replace the need for auto ownership, but limited survey research indicates that they may be adding more trips than they reduce. Uber has been shown to complement transit and even correlate with improved ridership, but research is limited both in data availability and scope of cities studied. Recent surges in technology that negates the need for trips, including Amazon, Grubhub, and the ability to work from home may also allow former transit riders to forgo their monthly passes and traditional commitment to riding transit. Low gas prices and a

strong economy, both correlated with higher amounts of driving, are perhaps playing a role as well. Research on all of these recent trends is limited.

In addition, shifting populations within metropolitan regions may also play a role in the recent decline in transit ridership. Gentrification has the potential to displace transit-dependent groups with populations more likely to drive, and trends such as the suburbanization of poverty make auto ownership even more likely for groups formerly likely to be regular transit users. Aging populations in cities may also be less likely to take transit. However, research on all of these factors is limited and largely inconclusive. Transit agencies' strategies involving fare technology and marketing are so far inconclusive. Demand-responsive, 'microtransit' pilots and network restructuring may be working to combat declines in ridership, but may also come with additional service that plays a larger role than has been acknowledged. Ultimately, the most conclusive evidence for maintaining and improving ridership remains an agency simply providing more service to its customers.

CHAPTER 3. DATA LIMITATIONS

Throughout this analysis and related studies I took part in, there were several significant potential ridership factors we were interested in studying, but were unable to draw conclusions about them due to lack of quality data. These factors appeared either in the literature as factors significantly correlated with transit ridership or in articles surrounding pilot projects with promising initial results. Despite this, they were either inconsistently measured geographically or between years, or they were not measured at all. A lack of data on these factors prevents researchers from performing rigorous studies on their effects, and may potentially hurt viable means of maintaining and growing ridership.

3.1 Dedicated Right-Of-Way

It is generally accepted knowledge in the transit industry that dedicated right-of-way (ROW) modes such as heavy rail are seen as more reliable and faster than mixed traffic modes such as streetcar and bus. Separating vehicles from general travel lanes allow them to travel faster and more consistently than those that sit in traffic. This, in turn, results in higher ridership per route mile on these modes. Cities that have implemented dedicated bus lane pilots, such as Boston, identified in Chapter 6, experienced higher ridership along these routes. As part of our group's study of strategies to combat ridership declines, we were interested in studying the effects of dedicated right-of-way on ridership on a nationwide scale. This type of study may have allowed us to see correlation between right-of-way for particular modes and ridership trends.

However, we were unable to complete this type of analysis due to a simple lack of reliable data. While metrics involving transit way mileage are available for each year in the national transit database (NTD), my analysis showed them to be unreliable. The first issue involves a change in the way NTD classified transit way mileage for non-rail modes. In 2012, non-rail “exclusive” and non-rail “controlled” right-of-way were reported for each mode. In 2016, categories were changed to “exclusive fixed guideway bus lane miles”, “exclusive high intensity bus lane miles”, and “controlled access high intensity bus lane miles”. This addition of “fixed guideway” mileage led many transit agencies to include numbers unrelated to exclusive ROW. For example, each operator of trolleybus service reported their mileage of trolley wire regardless of right-of-way characteristics. Some agencies reported fixed guideway mileage for traditional bus modes, rather than including these lane miles in “high intensity bus lane” mileage.

Another issue with transit way mileage data involves its general accuracy. Despite frequent campaigns to introduce bus lanes and segregate transit vehicles from other traffic, NTD data shows about as many agencies decreasing their dedicated right-of-way as increasing it. As shown in Figure 2 below, data from the NTD shows a relatively even spread of regional growth and decline in dedicated right-of-way mileage for otherwise mixed right-of-way modes such as bus and streetcar. The declines in dedicated right-of-way are more likely due to inconsistencies in reporting rather than actual guideway miles being repurposed for mixed traffic. The inconsistencies in reporting dedicated right-of-way mileage disqualify it as a metric for analysis, despite the interesting and potentially useful conclusions that may come from such an analysis. Future studies on implementation of

dedicated right-of-way on ridership and service efficiency are recommended, perhaps through data gathering from a large group of transit agencies themselves.

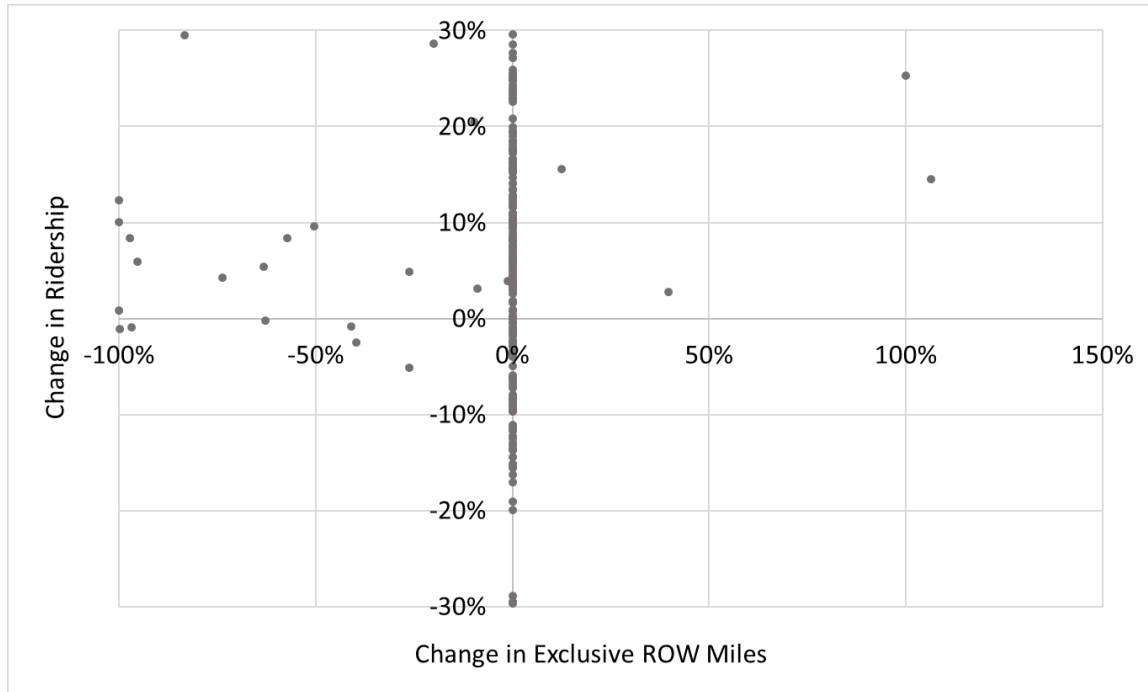


Figure 2 - Change in Ridership vs. Change in Exclusive Right-of-Way Miles by Metro Area

3.2 Reduced Reporters

Generally smaller agencies operating 30 vehicles or less, NTD reduced reporters have a different set of reporting requirements and apparent data standards than full reporters. While they are technically required to report unlinked passenger trips, vehicle revenue miles, and fare revenue, many of the holes in data we discovered were due to reduced reporters' lack of data for portions of our study period. While reporting requirements appeared not to change between 2012 and 2016, these missing data led us to

remove several agencies from the analysis. While it is important to note that many of these agencies lack resources to gather and analyze their data, this analysis took into account these smaller agencies which are often ignored in nationwide transit studies. Having reliable data available is the best way to guarantee a thorough analysis of these trends.

3.3 Mode Change

A byproduct of the multitude of transit modes currently in service across the US is their often complex categorization. Modes like bus rapid transit (BRT) and Streetcar blur the lines of what bus and rail services mean, and modes like hybrid rail may not be innately understood by all agencies. Even within a mode like streetcar, modern versions may act more like light rail than historic ones, which may affect their ridership and service characteristics. When agencies are given forms to report, many seemed to have reacted slowly to the introduction of new modes. For example, BRT systems in Cleveland and Boston were fully operational by 2012, yet they reported these statistics as motor bus (MB) that year. In 2016, this data was correctly assigned to BRT. This misrepresentation of mode statistics makes parsing historical data by mode unreliable, as service that acts like BRT may not be comparable at all to service that acts like MB.

A separate issue, related to the dedicated right-of-way issues above, is that several agencies have routes that behave like different modes along the course of their route. Examples include Boston's Green Line, which generally operates as light rail but with several segments running in mixed traffic as a streetcar, and Boston's Silver Line, which transitions from a dedicated busway to street running mid-route. These transitions must be handled in a logical way in data collection, either by correctly denoting right-of-way

mileage or assigning new modal categories based on combinations of other modes. This level of data would help future researchers sort through modal types to better identify ridership patterns.

3.4 Service Area

In our effort to compare transit service and passengers across hundreds of regions in the United States, the issue of regional scale became vital. Restricting comparison to municipal limits rarely makes sense as agencies themselves generally are not constrained to particular cities. Urbanized area (UZA), the geographic measure used by the NTD, is largely not available from sources like the US Census Bureau more fine-grain than every ten years. Urbanized areas have complex geographic boundaries that extend to the far reaches of a region, often reaching into nearby cities otherwise unaffiliated with a particular region. Because of their concentration on higher-density areas, UZAs tend to skew regional density high.

In contrast, Core-Based Statistical Areas (CBSAs) used in our analysis tend to include entire counties for the sake of simplicity. This allows for much more frequent data availability, but often includes hundreds of square miles of undeveloped land and skews density down for most regions. To compare transit service across regions of various size, we had to settle on CBSAs for data availability. This was not ideal, but was deemed necessary to complete the regional analysis.

However, agencies do report “service areas” to the NTD, technically required to conform to a geographic buffer surrounding the routes serviced by the agency. This metric would be ideal for a transit service analysis and for comparing densities of regions that

actually have operational transit service. However, the self-reported nature of NTD's service area left the data particularly unusable. Some agencies appear to simply report the square mileage of the counties they operated in without regard to service at all. Other agencies restricted their service area differently by mode. Both of these misrepresent what should constitute an agency's service area, though no methodology would be perfect. For example, commuters who drive in from outlying counties to park-and-rides generally are missed in a service area calculation. However, future studies would benefit from a specified methodology for determining an agency's true service area.

3.5 Tract Level Data and CBSA Changes

In our analysis, we relied on 1-year data from the American Community Survey (ACS) in order to accurately measure year-to-year variation in population and zero vehicle households. Unfortunately, this left us unable to perform an analysis on any scale smaller than the Core-Based Statistical Areas, as Census data on the tract and urbanized area levels are only available from the decennial census or as ACS 5-year estimates, which are not usable for comparisons of point-in-time data. Tract-level data would allow for remarkably fine-tuned analyses of trends not only related to transit, but of population and demographics in general. Metropolitan areas contain immense variation between their tracts, and the ability to track changes between non-decennial years would have vast impacts on the research world. Realistically, however, reliable year-to-year data would require a significantly scaled up effort by the US Census, particularly for all 74,000 census tracts at the 1-year level.

Additionally, CBSAs underwent a standard update in 2013 where many metropolitan and micropolitan areas gained or lost counties. This caused some issues with reconciling the demographic statistics between the years of 2012 and 2016. Documentation on the changes and how they affected population statistics was largely nonexistent. Piecing together data that was available, I was able to reconstruct some CBSAs to perform an accurate comparison of their 2012 and 2016 statistics. However, many CBSAs also had to be thrown out as their geographies could not be matched. Better documentation on these changes and how demographic statistics shifted would help researchers more accurately and thoroughly compare 1-year data from before and after the change.

3.6 Conclusion

Despite my confidence in my analysis, there were several data challenges that prevented this analysis from going further. Lack of nationwide reporting standards for certain metrics in the National Transit Database restricted our analysis and many others to basic reportable metrics. Geographic data limitations caused issues with data reconciliation and prevented a thoroughly nationwide study. Transit agencies must be able to accurately collect and analyze the data they can about their service and passengers, particularly at a time when transit ridership is declining. Quality data can help agencies and researchers alike to find the best answers to the many questions asked of them.

CHAPTER 4. PEER AGENCY TRENDS

My first look at transit ridership trends was a brief analysis of peer transit agencies. This section is centered on the Metropolitan Atlanta Rapid Transit Authority (MARTA), the primary agency in charge of local bus, heavy rail, streetcar, and demand response operations in the Atlanta area.

4.1 Background

Comparing a particular agency to its peers is a natural and relatively simple way to judge performance. Generally, agencies can use this analysis to identify their recent ridership, service, and reliability trends in the context of agencies with similar operating characteristics. By comparing agencies directly, practitioners can set goals for their agency to achieve the higher ridership of their peers, or particular service standards practiced elsewhere.

This approach does come with several drawbacks, however. A primary limitation of comparing peer agencies is the vastly different operating conditions experienced by different agencies. While dense cities may have an easier time attracting ridership, low-density cities will have to provide more or better service to achieve the same result. Additionally, many cities can have services split between agencies. For example, Sound Transit in Seattle appears to have low overall ridership for a transit agency operating in a relatively large market. However, this is due to that agency's operation of rail services alone while a separate agency operates bus services. In cities like Washington, DC, even commuter rail ridership is split between two separate agencies.

This chapter seeks to explore ridership and service trends of MARTA and its peer agencies. MARTA is the ninth-largest transit agency in the US by ridership. From the shell of a once-complex streetcar system, Atlanta was a bus-only city by the 1950s. MARTA took over these bus operations in 1971. At this time, it was becoming clear that the growing Atlanta region was in need of higher-capacity transit solutions than simply bus service. Spurred on partly due to oil crises, MARTA began constructing a heavy rail network in 1975. The most recent rail extensions opened in 2000, making MARTA a 38-station system operating over 48 miles of revenue track. The system operated in Fulton and DeKalb Counties in the Atlanta metropolitan area until 2015, when Clayton County joined. Outlying counties in the region generally rely on their own county transit operations and a separate commuter bus operator for rush hour trips to and from downtown. In 2018, MARTA acquired a 2.7-mile streetcar loop from the City of Atlanta, adding a new mode to its operations. Partly due to a bus network centered around rail stations, MARTA ridership is higher for rail than for bus.

4.2 Methodology

I identified peer agencies using a ranking of transit agencies by total ridership annually reported by APTA. Agencies considered “peer” to MARTA were those between around 50% and 200% of MARTA’s total annual ridership and generally operating both rail and bus modes. This method produced a list nearly identical to, and slightly more expansive than MARTA’s self-identified peer list. To ease comparison to MARTA’s bus and rail networks and parse potential peers separately for these distinct systems, I analyzed ridership by mode and formed two groups: mixed right-of way (ROW) and dedicated ROW. I defined mixed ROW as bus, trolleybus, commuter bus, and streetcar services.

These modes tend to operate among traffic and therefore are subject to different ridership factors than services with their own ROW. I defined dedicated ROW as heavy rail, light rail, commuter rail, hybrid rail, and bus rapid transit (BRT) services. In contrast to mixed ROW services, these operations tend to have short headways and are generally viewed as more reliable, therefore justifying a separate classification. A listing of these peer agencies and their ridership by mode and in total is shown in Table 1.

Table 1 - MARTA Peer Agencies

Agency	Region	2016 Mixed ROW ridership	2016 Ded. ROW ridership	Total
SEPTA	Philadelphia, PA	203,224,920	131,314,161	334,539,081
Muni	San Francisco, CA	172,084,368	49,489,553	221,573,921
Bay Area Rapid Transit	San Francisco, CA	N/A	136,246,897	136,246,897
King County Metro	Seattle, WA	141,669,561	N/A	141,669,561
Sound Transit	Seattle, WA	N/A	23,323,481	23,323,481
MARTA	Atlanta, GA	58,414,789	68,678,695	127,093,484
MTA Maryland	Baltimore, MD	76,550,989	27,970,115	104,521,104
Denver RTD	Denver, CO	73,252,352	28,902,487	102,154,839
Tri-Met	Portland, OR	58,292,800	40,749,370	99,042,170
Miami-Dade Transit	Miami, FL	63,644,812	31,325,176	94,969,988
San Diego MTS	San Diego, CA	50,737,469	38,168,880	88,906,349
Houston Metro	Houston, TX	66,813,249	18,228,011	85,041,260
Metro Transit	Minneapolis, MN	58,949,823	23,674,796	82,624,619
Dallas Area Rapid Transit	Dallas, TX	32,952,564	31,611,109	64,563,673
PAAC	Pittsburgh, PA	53,760,422	7,783,104	61,543,526

In addition to traditional MARTA peer agencies that operate both bus and rail, I also included two cities with rail and bus modes operated by separate agencies: Seattle and San Francisco. In Seattle, a busy bus network is run by King County Metro, with connections to a relatively new light rail network operated by Sound Transit. In San Francisco, Muni operates bus and light rail services in the city of San Francisco, while BART runs hybrid heavy rail and commuter rail services throughout the region. This demonstrates one of the drawbacks of an agency-to-agency comparison. Many regions have varying structures for the operation of transit services, but even separate agencies commonly work together to form part of a larger regional transit system. Regardless, the list above forms a clear image of agencies considered peer to MARTA in at least one mode.

An interesting feature of using this simple technique of selecting peers based on ridership is that agencies with higher than average ridership are fairly easy to group because there are so few agencies with over 1,000,000 annual trips. However, for mid-size and smaller agencies, ridership varies so little between agencies that selecting peers based on it distorts the meaning of the word “peer.” At that point, grouping by ridership produces a list of a variety of mid-size cities with very little in common operationally.

To view MARTA’s performance in context of its peers, I used ridership and service level data from the national transit database (NTD) adjusted database. I included service data to provide context for ridership gains and losses, and to see the varying effect of service changes on ridership for different agencies. I aggregated these agencies’ modes by the ROW characteristics described above, then plotted them month-to-month as far back as data was available, which in this case was 2002. Immediately upon creation of this graph, I noticed noise from varying month lengths and seasonality of ridership. To remedy this

noise, I used a 12-month lagging rolling average for the 12 months previous to a specific data point. This means that the figures begin in January of 2003, which is a sum of the data from that February 2002 through January 2003.

I also normalized all data to the first data point to eliminate differences in absolute ridership and service. This produces figures that begin at 100%, representing the value taken in January 2003. From here, agencies diverge as they gain and lose ridership and service. Because of the strong linkage between ridership and service levels, I saw the opportunity to display them next to one another as a way to demonstrate this relationship.

4.3 Results

I began by looking at agencies' overall trends before splitting by mode type. Figure 3 explores total ridership for all fixed route modes by agency normalized to 2003 levels. Demand Response modes have been excluded from this analysis. Clearly visible is the cyclical nature of transit ridership: nationwide ridership loss during the recession in early 2009 is reversed for most agencies in 2011 and 2012. Following about 2014, however, overall ridership flattens and begins to decline for many agencies once again. MARTA briefly surpasses its 2003 ridership in 2009 but there has been a generally downward trend since then, with ridership currently at its lowest point in nearly two decades.

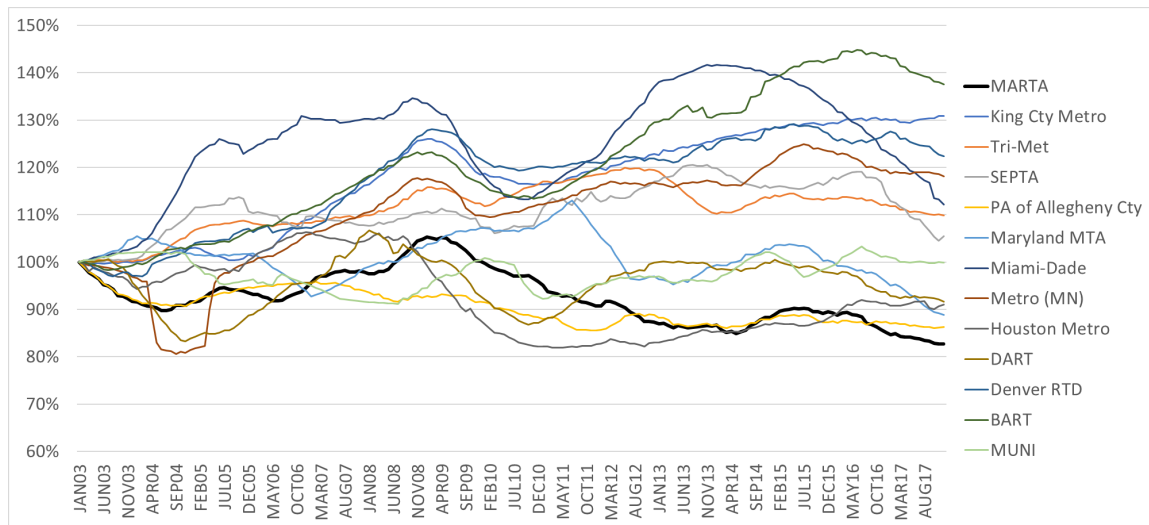


Figure 3 - Normalized Unlinked Passenger Trips by Agency - 12-mo Rolling Average, 2003-2017

Figure 4 shows vehicle revenue miles, a common indicator of service levels, since 2003. Programs to grow service can be seen by sharp upward slopes, and service cuts are indicated by sharp downward slopes. Across the board, service since about 2010 has been consistently trending upward. Immediately obvious is a sharp downward trend in MARTA service due to 2010 cuts. Service stayed flat for nearly three years before trending upward once again, though it still has not surpassed 2003 levels.

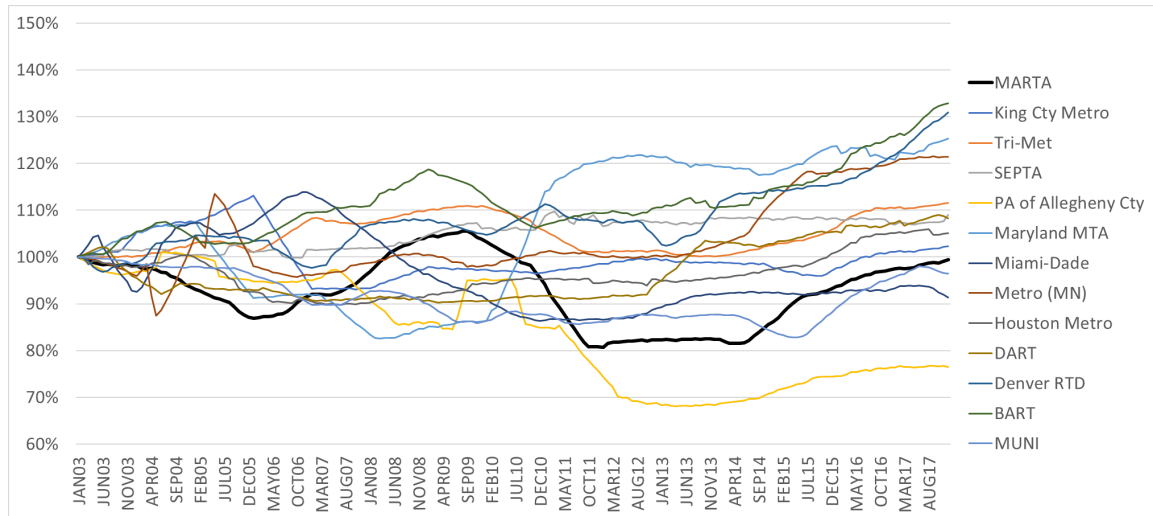


Figure 4 - Normalized Vehicle Revenue Miles by Agency – 12-mo Rolling Average, 2003-2017

In the next part of the analysis, I split modes by ROW type and analyze them in a more recent context. Figure 5 shows ridership for mixed right-of-way modes since 2012. A nationwide downward trend is visible post-2014 for every agency except King County Metro in Seattle. Despite some irregularities from SEPTA and the Maryland Transit Administration, MARTA has generally followed the trend of its peers, settling towards the middle of the group compared to 2012 ridership levels.

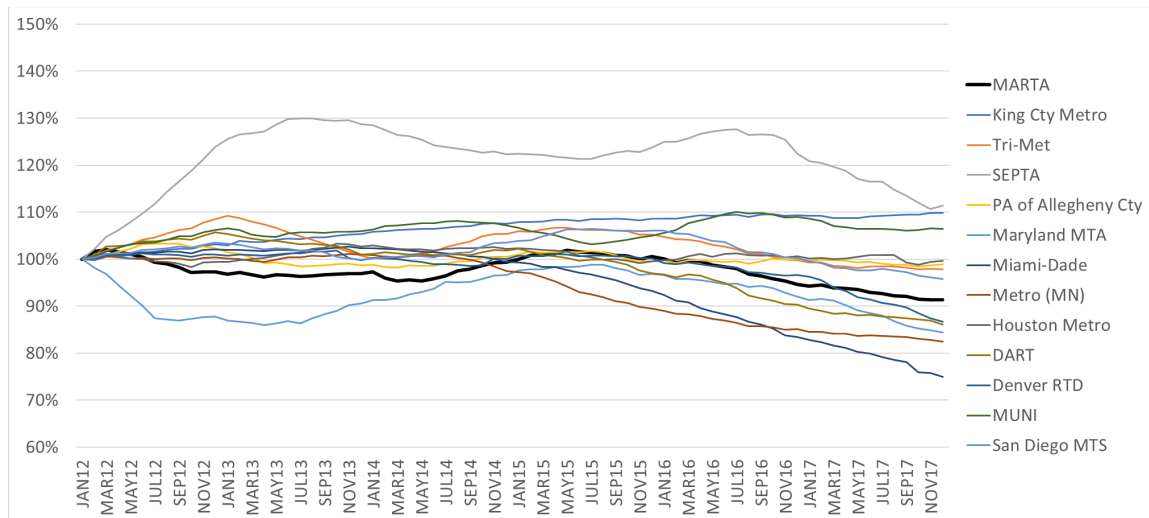


Figure 5 - Normalized Mixed Right-of-Way Unlinked Passenger Trips by Agency - 12-mo Rolling Average, 2003-2017

Figure 6 shows ridership for dedicated ROW modes since 2012. Here a different axis scale is required to show large jumps in ridership from several agencies, including Denver RTD, Sound Transit, Houston Metro, and Metro in Minneapolis-St. Paul. These jumps are the result of investments in new light rail lines and additional service which will be apparent in following figures. Aside from these outliers, ridership levels were relatively flat until 2015 and have since been dropping steadily. Again, MARTA is generally in the middle among its peers which have not added significant amounts of dedicated ROW service since 2012.

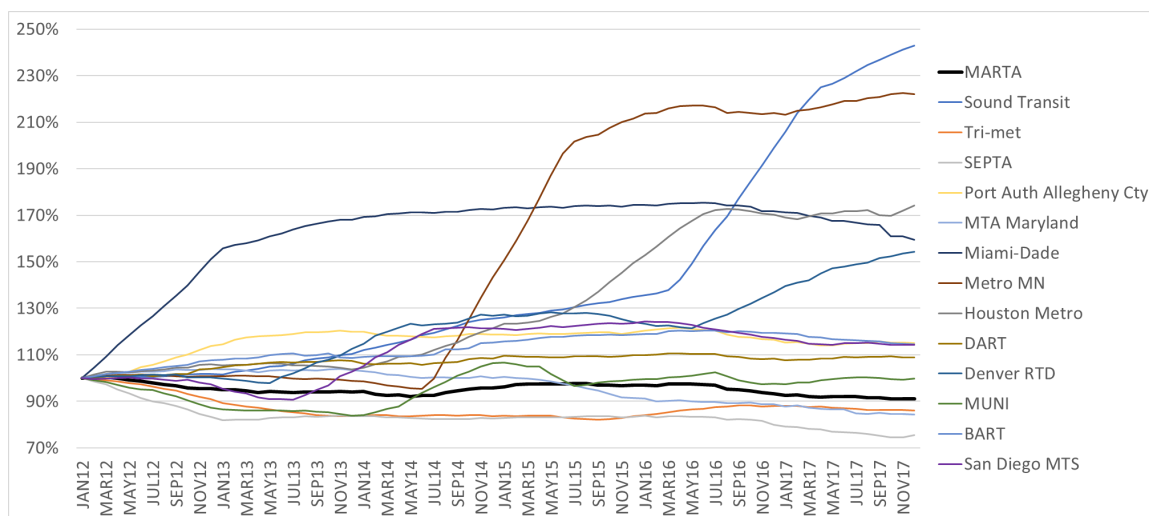


Figure 6 - Normalized Dedicated Right-of-Way Unlinked Passenger Trips by Agency – 12-mo Rolling Average, 2012-2017

Tables 2 and 3 list changes in service levels for mixed and dedicated ROW modes between 2012 and 2016. The color gradient indicates the level of change, with reds indicating a decline, greens an increase, and yellows little or no change. Mixed ROW service has generally increased by about 10% across the board. MARTA is no exception. Dedicated ROW, on the other hand, has seen service increase by approximately 40% on average, with MARTA around 25%. The agencies which expanded high-capacity service, including Denver RTD, Sound Transit, Houston Metro, and Metro in Minneapolis-St. Paul, are clearly recognizable. This phenomenon is consistent with a significant portion of the literature on the strong relationship between service provided and ridership (Taylor et al., 2009; Dill et al., 2013; Kyte et al., 1988; Kain & Liu, 1999; Boisjoly et al., 2018).

These tables illustrate two trends that have taken place for MARTA and peer agencies over the past several years. First, that service has been increased nearly

everywhere and for all modes, but with the only positive ridership effects coming from a few agencies' enormous investments. This seems to indicate a force pushing back against ridership gains that only massive increases in service have been able to overcome. Second, the majority of investments in service have been in dedicated ROW modes, primarily in the opening of new light rail services. These service increases have seen corresponding ridership increases, but generally not on a level consistent with the amount of service invested. This indicates further a force holding ridership down. Overall, there appears to be more affecting ridership than simply service provided, indicating a need for further analysis with more agencies and regions considered.

Table 2 – Service Changes by Agency 2012-2016, Mixed Right-of-Way Modes

Agency - Mixed Right-of-Way	Vehicle Revenue Miles Change	Vehicle Revenue Hours Change	Vehicles Operated in Maximum Service Change
King County Transit	101.87%	109.60%	108.99%
Tri-Met	106.82%	111.07%	106.05%
Sound Transit	103.46%	110.81%	111.03%
SEPTA	98.12%	100.19%	99.06%
Port Auth of Allegheny Cty	111.79%	109.27%	108.35%
Maryland Transit Admin	100.61%	94.84%	112.77%
MARTA	113.16%	110.74%	106.47%
Miami-Dade Transit	101.48%	103.35%	102.17%
Metro Transit (MN)	108.45%	106.62%	101.33%
Houston Metro	105.03%	112.87%	96.04%
Dallas Area Rapid Transit	109.38%	112.12%	104.50%
Denver RTD	109.66%	106.19%	106.20%
Muni	111.82%	113.78%	121.13%
San Diego MTS	119.28%	118.37%	121.05%

Table 3 – Service Changes by Agency 2012-2016, Dedicated Right-of-Way Modes

Agency - Dedicated Right-of-Way	Vehicle Revenue Miles Change	Vehicle Revenue Hours Change	Vehicles Operated in Maximum Service Change
Tri-Met	114.76%	117.74%	111.11%
Sound Transit	145.53%	150.54%	142.01%
SEPTA	101.59%	116.52%	100.18%
Port Auth of Allegheny Cty	111.98%	112.41%	106.64%
Maryland Transit Admin	97.79%	98.22%	104.46%
MARTA	125.27%	123.64%	111.63%
Miami-Dade Transit	115.11%	128.39%	112.86%
Metro Transit (MN)	223.13%	277.85%	184.78%
Houston Metro	370.15%	387.25%	304.35%
Dallas Area Rapid Transit	122.80%	117.43%	103.24%
Denver RTD	154.14%	166.96%	154.90%
Bay Area Rapid Transit	113.79%	114.58%	102.11%
Muni	101.19%	101.67%	106.94%
San Diego MTS	115.38%	111.28%	104.30%

Additionally, while this peer grouping tends to follow similar trends to MARTA, the group may consist of regions that are not fundamentally similar enough to Atlanta to have a bearing on the judgement of ridership change. For instance, Pittsburgh is a region with less than half the population of Atlanta, and its older origins have influenced significantly different building patterns. While they both operate bus and rail services, MARTA and the Port Authority of Allegheny County share little else. It is in this context that a grouping of peer regions is appropriate, where demographic and built environment factors can be included and analyzed alongside ridership and service.

CHAPTER 5. GROUPING TRANSIT DATA BY METROPOLITAN AREA

In many cases, viewing transit ridership at the agency level is not sufficient for studying trends. Because transit agencies generally operate services locally or region-wide, it is often useful to talk about transit at the regional level. Even more useful is the ability to integrate further data sources, such as from the American Community Survey (ACS). In this way, regions may be compared directly, using census-designated boundaries, and a wide variety of demographic factors can be analyzed alongside transit ridership to further inform factors affecting ridership. Unfortunately, there are very few built-in methods to piece transit data sets together with data such as the ACS. This severely limits the usefulness of the vast amounts of data contained in the national transit database (NTD) and other data sources.

In this chapter, I develop a method for attributing transit statistics, which are primarily tied to an Urbanized Area (UA), to Core-Based Statistical Areas (CBSAs), which are used in census data. This method was used to prepare data for a cluster and trend analysis that was performed by my colleagues Dave Ederer and Dr. Simon Berrebi. My role involved collecting, cleaning, and aggregating NTD data for a point in time, then proportioning it by CBSA, cleaning it once again, and attaching it to relevant ACS data. My colleagues then used this CBSA-level data by mode in a cluster analysis to form peer region groupings. Finally, they analyzed changes within these groups over time, this time using my prepared CBSA-level data for two points in time. For the purposes of demonstration of the method, some of the results of this paper are shown in this chapter.

The full paper involving clusters is forthcoming, and may be found in the references section under Ederer et al. (2019). Though this specific case used the prepared data for a cluster analysis, this method can be applied to any study requiring the use of transit data at the CBSA level.

5.1 Background

Grouping agencies by region is important for a variety of reasons. Perhaps most vital is that different regional agency structures do not separate out into their own cases. In other words, grouping all regional agencies ensures that all of the region's transit service is captured. Cities such as San Francisco, for instance, have different agencies operating bus, light rail, heavy rail, and commuter rail networks. In Boston, however, all of these modes are operated by the same agency. Simply observing one agency in San Francisco misses a sizeable amount of transit service offered in that area. Ultimately, logic dictates that passengers are more concerned with a transit network serving their trip than the particular operator of the legs of that trip. By grouping all agencies together, all of the region's trips may be analyzed at once.

Another benefit of grouping by region is the ability to include demographic and built environment factors in the analysis. When looking at agencies, service areas are often difficult to define and can vary wildly between agencies based on jurisdiction. At the regional level, however, US Census data is plentiful and well-defined. When it came time to cluster regions into groups, Census data was necessary to establish the population, percent of households with zero vehicles, and the percent of the population living in dense tracts.

Drawbacks of grouping at a high level mostly revolve around the relevance of attaching transit statistics to an entire CBSA when significant portions of many CBSAs are unserved by transit. The requirement of using data at the CBSA level is the result of limited data availability from the Census. Urbanized Area, denoted as UZA in NTD data and UA in Census data, forms a boundary around the areas of a region that are sufficiently “urban.” An example of the differences between UA and CBSA is shown in Figure 7. Shaded regions represent UAs, while the yellow boundary represents the Charlotte CBSA. UAs naturally fit well with transit data, as the vast majority of transit service is provided within the boundaries of a region’s UA. However, Census data at the UA level is only published for the decennial census, restricting recent applications of that geography to 2000 and 2010. CBSA-level ACS data, however, is annually published for one-year and five-year estimates, and therefore became the necessary unit of geography. My task was then to link UA-level NTD data to CBSA-level ACS data.

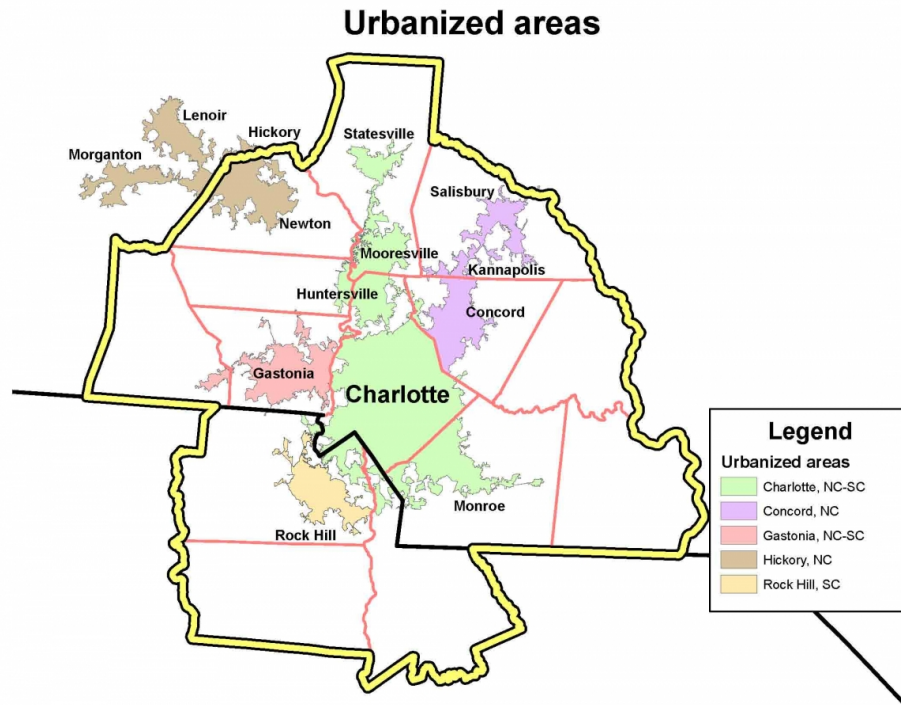


Figure 7 - Comparison of UA and CBSA Levels. Citation: Chesser & Newsom, 2012

5.2 Methodology

For the cluster analysis, four factors were identified to be key to creating groups of regions: Population, transit operating expenses, percent zero vehicle households, and percent of the population living in dense census tracts (“percent dense”). These factors were derived from relevant factors in the literature as well as the specific goals of the cluster analysis. Population is one of the most logical predictors of ridership, as an agency’s growth is primarily limited by the number of people living within its service area. Operating expenses were seen as a measure of a region’s fiscal limitations on ridership growth. After all, an agency with a larger operating budget has a much better chance to provide enough service to generate high ridership than one with a limited budget.

Percent zero vehicle households served to represent a “transit captive” population, or one that is far more likely to take transit than a population with easy access to a vehicle. This number generally represents two groups: one that does not have the financial or physical means to own or operate a vehicle, and one that may have the means, but chooses not to own a vehicle for a variety of reasons. This measure does have its drawbacks, as a key factor in growing ridership involves capturing growth from “choice” riders who have other options. Additionally, the use of the household unit sacrifices a significant degree of accuracy; for example, a five-person household with one car may include several transit captive people who are not represented in the zero-vehicle household metric.

Finally, percent dense attempts to measure the population in a region that lives in an area suited for at least hourly transit service. This measure fails to take into account built environment and a variety of other factors, but it at least gives a rough estimate of the dense population in each region. After the analysis, comparisons of ridership and VRM were planned, so a wide variety of data had to be prepared for the analysis.

For the above statistics, I cleaned and prepared two sets of data. The first set was used in the clustering process. For this purpose, ACS five-year data was used in population, zero vehicle households, and percent dense metrics. Five-year estimates have a larger sample size and is therefore more representative than one-year data, and because the data for the clustering process needed to simply represent a region in general, there was no need to identify a point in time. Transit operating expenses were converted to CBSA-level using the method below, and then tied to the CBSAs represented in the ACS data. Next, I prepared the second set of data to be used in the analysis of trends across time, which required data to be refined to a one-year level. Therefore, ACS one-year data was used for

population and zero vehicle household calculations. Due to the small geography that tract-level data covers, percent dense was not available for small sample sizes like the ACS one-year estimates, so it was excluded from the trend analysis. Data from NTD for unlinked passenger trips (UPT) and vehicle revenue miles (VRM) were converted using the below method in order to be used in the analysis of trends within clusters.

In the first step in the data preparation process, percent dense was calculated using ACS five-year estimates for housing unit density at the census tract level. First, census tracts with at least three housing units per gross acre were highlighted in the data. This number has commonly been cited as “transit-supportive density” for several decades (Pushkarev and Zupan, 1977). The population of these tracts were summed for each CBSA, which was then divided by the total population of that CBSA to determine the percent of the population residing in dense tracts.

In the next step, I converted NTD data to fit the CBSA level. This process first involved the summation of each relevant statistic by transit mode across operators in each UA using the NTD monthly adjusted database. This produced a data set with UA-level summaries of transit service by mode. I then used a geography relationship data set published by the census to perform the conversion. This dataset contained information on the percentages of a UA’s population living within a given CBSA and vice versa. In other words, a UA entirely contained within a CBSA would be assigned a value of 100% for that CBSA. Using this data, I was able to proportion transit statistics to each CBSA based on population. It was often the case that multiple UAs had at least a portion of their population within a particular CBSAs, in which case I aggregated these statistics by CBSA. It was also

often the case that a UA fell between two CBSAs, and I would then proportion ridership according to the population contained in each.

This method did have several drawbacks. Primarily, I made the assumption that ridership, VRM, and operating expenses are roughly proportional to population. There are certainly examples where this is not the case, but due to a lack of spatial transit data on a nationwide scale, I deemed the division of resources by population to be the most accurate method available. Additionally, the proportioning method and the often complex geographies of UAs created a few cases where far-flung suburbs and small towns were assigned significant amounts of transit service that was not realistically operated near them. In one example, the Allentown, PA CBSA was assigned a proportion of Philadelphia's heavy rail statistics, despite Allentown laying over 45 miles away from the nearest station. To fix this, I applied a filter on the proportion of UA data assigned to a CBSA. The filter dictated that data would only be assigned to CBSAs if at least 10% of the UA's population fell within its boundaries. This filter served to contain most statistics within the CBSA where they occurred.

5.3 Example Application of the Method

Once the above methods were applied, data from the NTD and ACS could finally be used in conjunction. This data was a fundamental requirement in a project to form clusters containing regions of similar transit-operational characteristics. Each cluster represented a grouping of regions based on the four factors listed above. Two groups of clusters were formed, one for mixed and one for dedicated right-of-way (ROW) modes. These modal divisions are identical to the divisions used in previous chapters. Once modes

were grouped into ROW types for each region, these regions were then clustered using Ward's method. This method attempts to minimize the statistical differences within a cluster while maximizing differences between clusters. It also tended to produce consistently-sized clusters, which makes them more useful for peer analysis.

The resulting mixed ROW clusters are shown on a map in Figure 8. Clusters tended to form fairly logical groups overall. Cluster 1 contained mostly older, formerly industrial cities in the Northeast and Midwest, in what may be referred to as the “rust belt.” Among these mid-size cities are Baltimore, Pittsburgh, and Cleveland. Cluster 2 also contained mid-size cities, but tended to include more recently developed and auto-oriented regions like Charlotte and Wichita. Cluster 3 included all of the smaller towns operating bus service. Cluster 4 included classic examples of sprawl, with large populations spread out over great amounts of land. These auto-oriented regions include Atlanta, Houston, and Phoenix. Cluster 5 included the large, dense cities better suited for transit service than those in Cluster 4. Among these regions are Philadelphia, Chicago and Seattle.

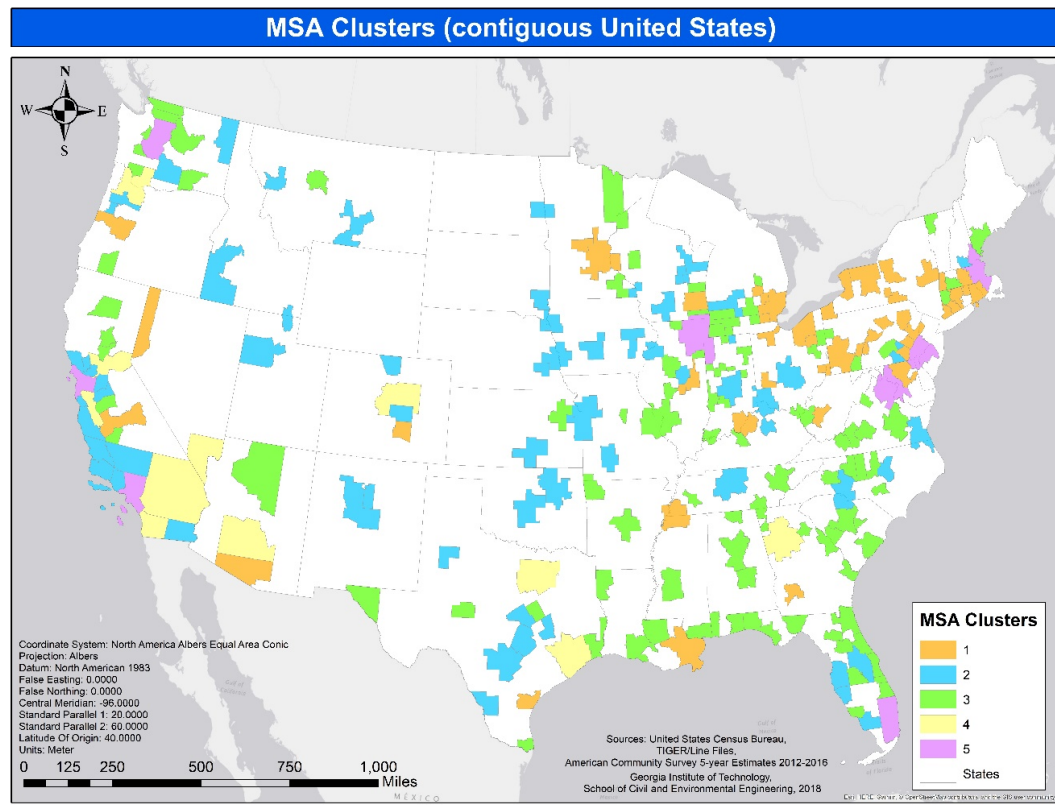


Figure 8 - Mixed Right-of-Way Core-Based Statistical Area Clusters. Credit: Taylor Gibbs

For dedicated ROW modes, there were far fewer regions included, which leads to different combinations of regions despite the groupings remaining fairly logical. A dendrogram of the clusters is shown below in Figure 9. Los Angeles formed its own cluster in large part to its high population. Large, dense cities once again formed their own cluster, including San Francisco, Washington, and Boston. These first two clusters represent most of the heavy rail ridership in the country. The next cluster includes mostly “sun belt” cities, representing low-density but heavily populated regions such as Atlanta and Charlotte, but

interestingly also Minneapolis and St. Louis. Another cluster diverged near this one, including mostly western auto-oriented cities with smaller populations, including Portland, OR and Denver. The final cluster once again included “rust belt” type regions, such as Cleveland and Buffalo. The final three clusters include most of the country’s light rail ridership.

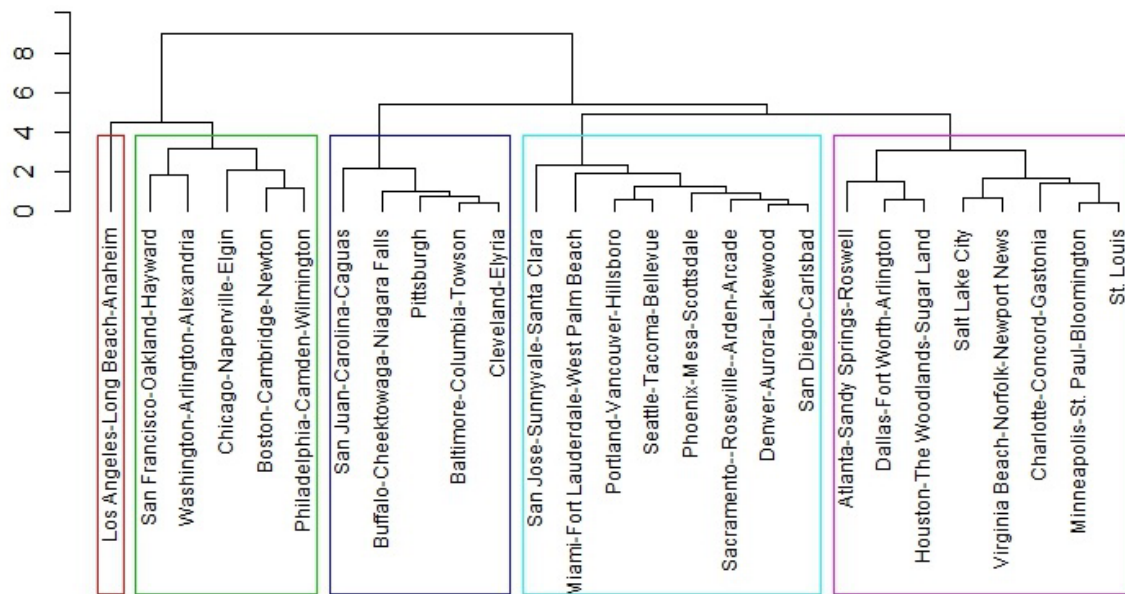


Figure 9 - Dedicated Right-of-Way Cluster Group Dendrogram. Credit: Dave Ederer

Noticeably, Atlanta is grouped among a different set of peers than MARTA’s self-identified list. Houston, Dallas, and Denver remain for mixed ROW, but new peers include Las Vegas and Sacramento. For dedicated ROW, which makes up the majority of MARTA’s ridership, Atlanta is grouped with familiar peers like Houston, Dallas, and Minneapolis, but also with much smaller regions including Virginia Beach and Salt Lake City. The grouping of Atlanta with much smaller regions may indicate that much of Atlanta

has a similar built environment to smaller cities, namely low-density sprawl. Additionally, a small operating budget may have a bearing on these groupings, and may in fact indicate a particularly small transit operating budget per capita in Atlanta.

Once these cluster groupings were established, trends in ridership and service between 2012 and 2016 were evaluated for each of them. In this example, Atlanta's mixed ROW cluster is shown in Figure 10 with ridership change plotted against service change. Surprisingly, the relationship between change in service and change in ridership appears reversed, so that more service over time appears to predict less ridership. While the two are loosely correlated at best, and the result is somewhat of an anomaly, it is an interesting result nonetheless. Additionally, in all clusters but this one the relationship was positive but the intercept was negative. This result indicates an outside variable that suppresses ridership even in the presence of additional service. In other words, it takes a substantial amount of additional service to add a small amount of ridership, with values varying significantly across agencies and clusters. This outside variable indicates a need for further study of recent changes in ridership.

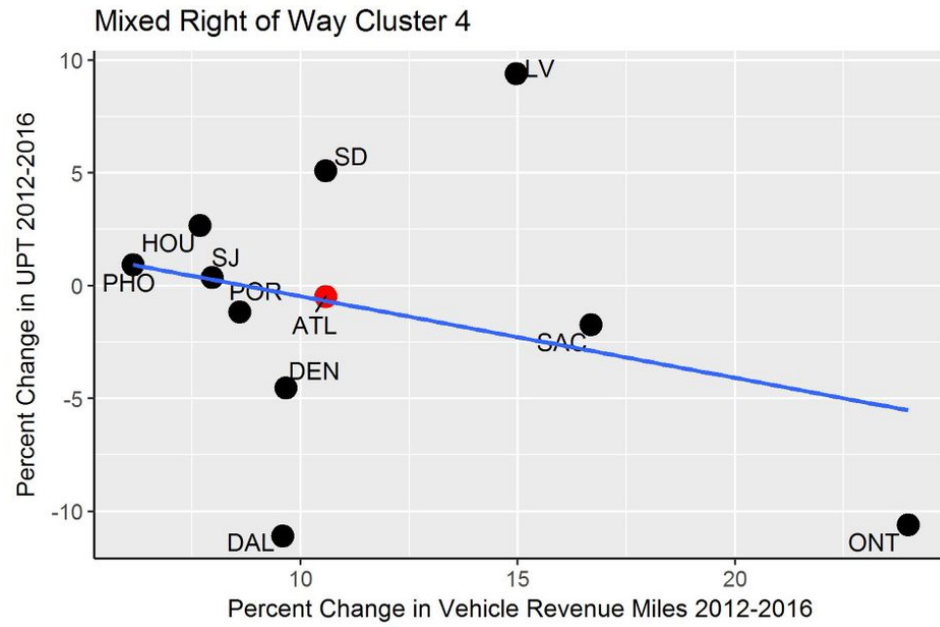


Figure 10 - Change in Ridership vs. Change in Vehicle Revenue Miles 2012-2016 for MARTA's Cluster. Credit: Dave Ederer

CHAPTER 6. CASE STUDY AGENCY ANALYSIS

The exploration of trends in transit ridership nationwide reveals that a great majority of transit agencies have seen ridership declines in recent years. This phenomenon begs the question of what sorts of strategies agencies can use to combat this decline, and the degree to which these strategies have been successful. In the case of widespread declines, even stagnating ridership can be seen as a positive outcome, yet still many agencies struggle to maintain their current riders even as populations grow.

This section explores ten case study agencies, their trends in ridership, service, and reliability, and their strategies to retain riders. Agencies were selected based on the goals of achieving diversity in agency size, metropolitan area type, strategy type, and preliminary success of their strategy. Five of the agencies operate some form of rail service, while the other five operate only bus service. Select agencies were also interviewed for further details on the planning, implementation, and results of projects aimed at growing and maintaining ridership. A list of the case study agencies is shown in Table 4.

Table 4 - Case Study Agencies

Agency	Region	Bus Modes	Rail Modes	2017 Total Ridership
King County Metro	Seattle, WA	Bus, Trolleybus	Streetcar	122,874,336
Spokane Transit Authority	Spokane, WA	Bus		10,264,971
MBTA	Boston, MA	Bus, Trolleybus, Bus Rapid Transit	Heavy Rail, Light Rail, Commuter Rail	372,189,150
Greater Portland Transit District	Portland, ME	Bus		1,850,686
Maryland Transit Admin.	Baltimore, MD	Bus, Commuter Bus	Heavy Rail, Light Rail, Commuter Rail	97,084,688
PSTA	St. Petersburg, FL	Bus, Commuter Bus		11,439,966
Metro Transit	Minneapolis, MN	Bus	Light Rail, Commuter Rail	81,927,424
Connect Transit	Bloomington, IL	Bus		2,313,159
IndyGo	Indianapolis, IN	Bus		8,754,767
Houston Metro	Houston, TX	Bus, Commuter Bus	Light Rail	85,214,650

Trend data for ridership, vehicle revenue miles (VRM), and average speed come directly from the national transit database (NTD)’s monthly adjusted database. Average speed is calculated by dividing VRM by vehicle revenue hours (VRH), effectively forming a “miles per hour” for scheduled services. These first three values are then displayed as a 12-month rolling average of the previous 12 months of data, and are normalized to January

2012 values to show their trends. The rolling average is used to smooth out noise from individual months and the seasonality of ridership. This noise naturally occurs as a product of using monthly data with varying number of days per month. It is important to note that due to the 12-month lag, a data point at January 2012 is actually representative of February 2011 through January 2012. Therefore, instantaneous changes in ridership begin to appear on the month they occur, but take a full year to fully register on the graphs.

On-time performance (OTP) data is pulled from agency websites, and varies greatly in detail and range of available information. Variation between agency standards of what constitutes “on time” means that individual on-time percentages are difficult to compare across agencies. When normalized, however, they show a trend across time that makes these comparisons possible. Where available, data is reported as a lagged 12-month rolling average in a similar fashion as described above. It is also normalized to the earliest data point reported, though this is often a different point in time than the rest of the data. For example, many agencies’ first available OTP data is in January 2012, so the first 12-month rolling average point is in December 2012. By the same token, no data actually includes the year 2018. What appears to be 2018 is actually the point representative of the entire year 2017.

What follows is a summary of all ten case study agencies. Figures are all at the same scale except three specifically indicated otherwise. Rail modes are separated from bus modes in the same manner as previous sections besides one important difference. Here, bus rapid transit (BRT) is categorized as bus and streetcar categorized as rail to help illustrate how changes in right-of-way (ROW), speed, and reliability can affect the performance of a particular mode.

6.1 King County Metro, Seattle, WA

King County Metro is the primary operator of bus service in the Seattle region, and the agency also operates two streetcar lines. Seattle's light rail and commuter rail services, while working cooperatively with King County, are run by Sound Transit, a separate entity. Lately, Seattle has been featured frequently in the press about the region's dramatic shift from driving to transit. Light rail openings have certainly boosted these effects, but King County Metro in particular has managed to continually increase bus ridership over the past several years, a feat very few other agencies have accomplished, especially given relatively little service additions over the same period.

Key trends for bus and streetcar service are shown in Figures 11 and 12. On-time performance is reported monthly for all bus operations, with data going back to 2012. Therefore, OTP is shown as a 12-month rolling average normalized to January 2013 levels. This graph shows some remarkable feats accomplished by King County Metro. Despite a consistent degradation of average speed, bus ridership has followed an upward trend since 2012, and has remained roughly flat since mid-2016. On-time performance appears to correlate well with VRM, both remaining fairly steady. Streetcar trends were placed on a different scale than the rest of the figures due to dramatic increases following the opening of the First Hill Line in 2016, nearly tripling the system's length.

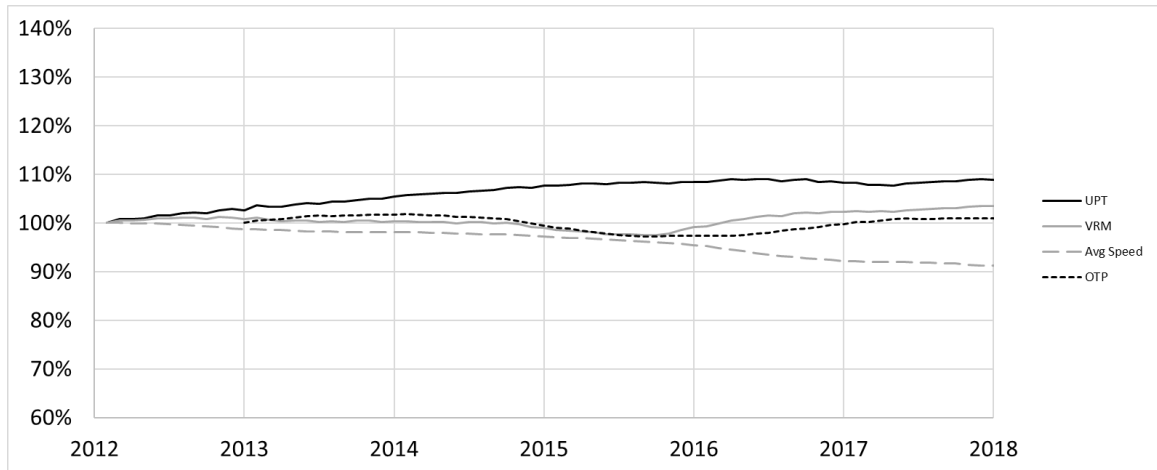


Figure 11 - King County Metro Normalized Bus Systemwide Trends

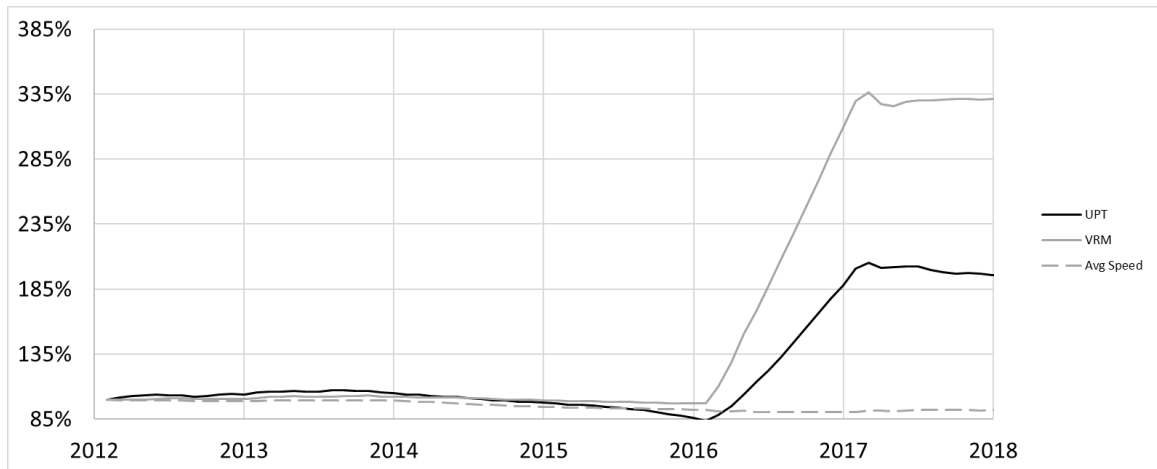


Figure 12 - King County Metro Normalized Streetcar Systemwide Trends

Interviews with the speed and reliability group at King County shed some light on these trends and some tactics underway to improve them further. Regarding speed, the group mentioned an increase in traffic within Seattle causing buses to gradually slow. However, they also mentioned that increased ridership has slowed buses down due to high

dwelling times, and so generally service is added in an attempt to speed routes up. This tends to conflict with the assumption that additional service is put in place to attract riders, when perhaps it is simply a reaction to crowding. Regarding improvements, the group's main focus is on constant small spot improvements wherever they can be made. These may be as small as parking restrictions to help buses access a stop and save a few seconds each trip. However, larger projects such as bus lanes, signal priority, and re-timing are also included in the program, often on a corridor level to help improve several routes at once. The group said that coordination with city and state departments of transportation is key to getting the improvements in place in a timely manner.

6.2 Spokane Transit Authority, Spokane, WA

The Spokane Transit Authority is the sole provider of bus and demand-response service in Spokane County, WA. Public takeover of Spokane's bus routes took place in 1968 after years of declining revenues. A public transportation benefit area was established in 1980 to devote sales taxes to transit, and the Spokane Transit Authority was created alongside it. Today, the agency operates 36 fixed routes, most of which run through a downtown transit center. Five routes provide frequent, fifteen-minute or less service all day. Recent efforts include the extension of service hours and frequency of service across the system starting in early 2017. There are plans to extend the service area of the agency to the nearby Coeur d'Alene metropolitan area in 2025.

Key trends are shown in Figure 13. Despite some growth early in the decade, ridership in Spokane dropped by nearly 10% between 2015 and 2017. On-time performance tracks similarly to ridership, gradually decreasing beginning in mid-2017.

VRM and average speed have remained fairly constant. However, by the end of 2017, every statistic appears to be pointing upward, perhaps due to the agency’s most recent strategic plan to increase service and ridership.

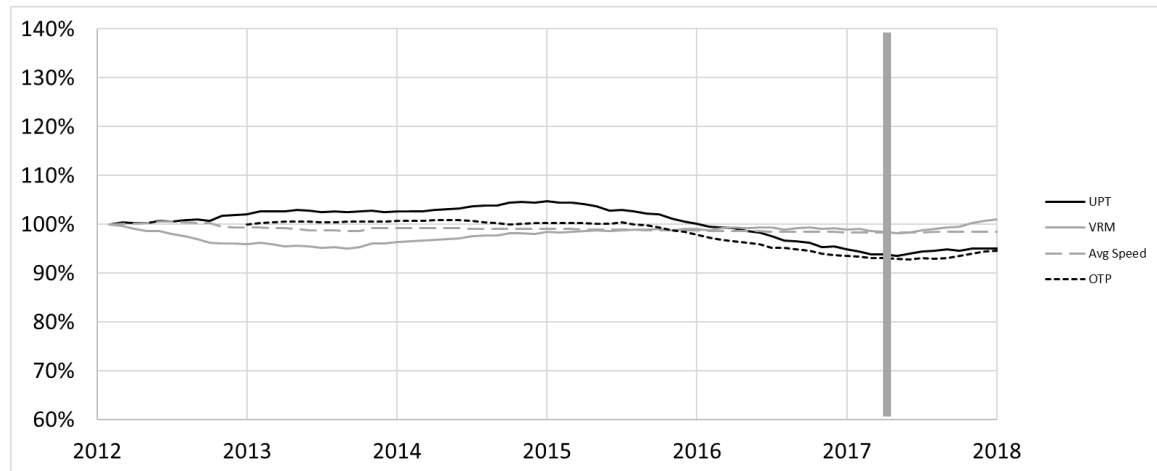


Figure 13 - Spokane Transit Authority Normalized Bus Systemwide Trends

6.3 Massachusetts Bay Transportation Authority, Boston, MA

The Massachusetts Bay Transportation Authority (MBTA) operates bus, light rail, heavy rail, and commuter rail in the Boston metro area. The largest case study agency by ridership and route miles, the MBTA operates some of the oldest rail lines in the country, including the first subway in the US. The MBTA system revolves around three heavy rail lines and one branched light rail main line that meet in downtown Boston. There are 177 bus routes, five bus rapid transit (BRT) routes, and thirteen commuter rail routes filling out the rest of the system.

The MBTA was formed in 1964 as a replacement for Metropolitan Transit Authority, itself a public replacement for the private operation of transit in Boston. Many cuts in service and track mileage occurred in the latter half of the 20th century, as routes were abandoned as they lost ridership. Major openings include the Silver Line BRT in 2002, followed by a series of extensions and expansions of that system until the present day.

Recent projects to improve ridership primarily focus on speeding up buses on select routes. In a partnership between the city and the MBTA, a temporary bus lane was created in the Roslindale neighborhood along Washington St., one of the city's busiest routes, in May 2018. The temporary lane was originally set with orange cones blocking off a single inbound lane to cars between 5-9 AM on weekdays, allowing only buses and bikes to travel in the lane. The results were a decrease in travel time by 20 to 25% during rush periods. In response to overwhelming support from bike and transit riders, the city made the bus lane permanent after the end of the four-week implementation period (City of Boston, June 2018).

Trends for bus, commuter rail, and heavy and light rail ridership and service are shown in Figures 14, 15, and 16 below. The MBTA reports highly detailed OTP data, aggregated by individual day and mode. Daily OTP data became public in 2016. Unfortunately, bus OTP data only goes back to 2015, and rail OTP data only became available in March 2016, and it is therefore excluded from the figures. Bus data includes the Silver Line BRT.

Of note is a large spike in bus ridership in mid-2015 followed by steady declines. Rail ridership also held off declines until about 2015. This date of the start of declines is among the latest in all of the case studies, and perhaps indicates a benefit of a larger, more robust system. VRM and speed remained somewhat constant over the period for both bus and rail, indicating that any route-level bus lane or reliability pilots tend not to affect system-wide numbers.

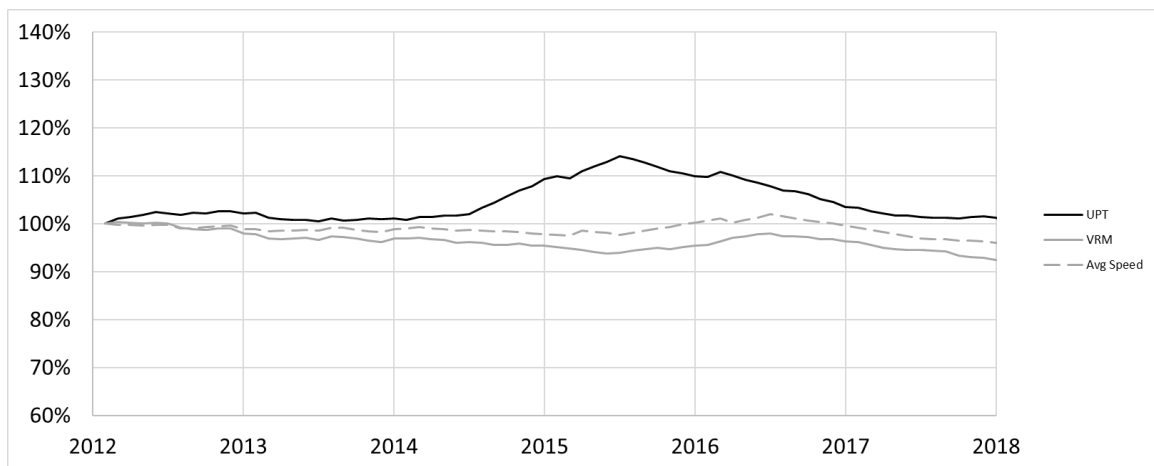


Figure 14 - MBTA Normalized Bus Systemwide Trends

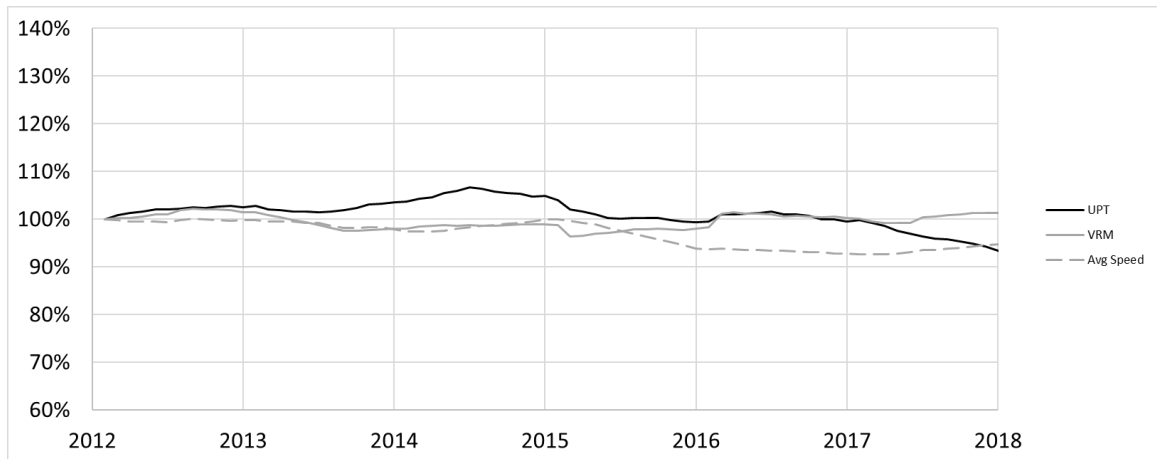


Figure 15 - MBTA Normalized Heavy Rail and Light Rail Systemwide Trends

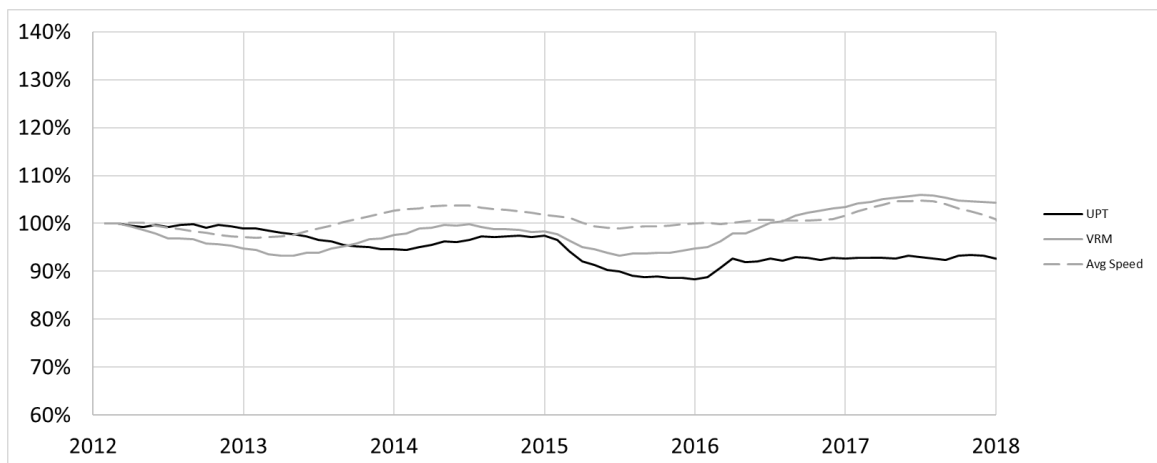


Figure 16 - MBTA Normalized Commuter Rail Systemwide Trends

6.4 Greater Portland Transit District, Portland, ME

The Greater Portland Transit District operates fixed route bus services in Portland, Maine. Founded in 1966, the agency went through several decades of declines in service area and ridership. In 2004, the agency began expanding again, and improvements have

come quickly since then. A 2013 bus priority study recommended a series of improvements to a street that would help speed up buses. Of the strategies identified, two signals have been modified and an in-line bus stop has been implemented prior to 2017. Phase I of construction of bump outs and lane changes started in 2017. In 2015, free rides for high school students began, and Sunday service was increased. An express bus service was added in 2016. The city is also undergoing a series of progressive enhancements, such as changes to zoning code that allows developers to pay a fee in lieu of meeting minimum parking requirements.

Trends relating to the Greater Portland Transit District are shown below in Figure 17. Unfortunately, OTP data was not publicly available. Portland shows a fairly remarkable trend since mid-2015 surrounding ridership: nearly 30% growth. A sizeable portion of this ridership may be attributed to incoming high schoolers following the elimination of yellow bus service in 2015, indicated on Figure 17. However, ridership continues to grow, and service levels and average speed have steadily grown since 2016 as well.

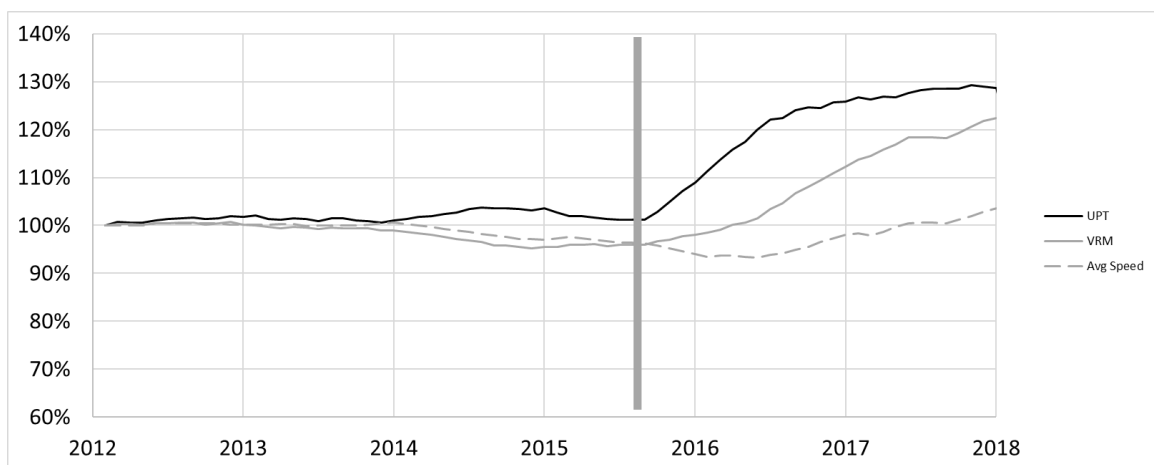


Figure 17 - Greater Portland Transit District Normalized Bus Systemwide Trends

6.5 Maryland Transit Administration, Baltimore, MD

The Maryland Transit Administration (MTA) provides bus, light rail, heavy rail, and commuter rail service in the Baltimore, MD region. Commuter trains also serve the Washington, DC region. The MTA took over operations in 1970 primarily as a bus system. The Metro Subway heavy rail line opened in 1983, serving northwest suburbs and downtown Baltimore. This was followed by a light rail line in 1992, serving north suburbs, downtown, and the Baltimore airport. Plans for further light rail expansion never came to fruition.

Recent efforts include a complete overhaul of bus services. Between 2015 and 2017, several routes were rebranded and the system reworked to provide BRT-ready color-coded lines with 24-hour service and high frequencies radiating from the city center. Additionally, connecting local buses were planned to form rings around the city to bridge gaps in service, and peak-period express buses would create fast links to downtown. The MTA's stated goals were to provide better and more frequent service city-wide and to strengthen connections between bus and rail (Maryland Transit Administration, 2017). The system went into effect in June of 2017 to much fanfare and high expectations (Dovak, 2017). This system change is indicated on Figure 18 below, but it occurs too late in the data for an effect to be observable.

An analysis of recent trends for bus, commuter rail, and heavy and light rail is shown below in Figures 18, 19, and 20. MTA's ridership trend follows an interesting curve, first growing from 2013 to 2015. However, following the redesign, ridership has begun to plummet, falling nearly 15% from its peak in 2015. Rail ridership followed a similar

downward trend following 2015. VRM, average speed, and OTP have all remained steady or improved over the same period for both bus and rail modes. Unfortunately, OTP data is available only on a fiscal year basis, and only reliably until 2016.

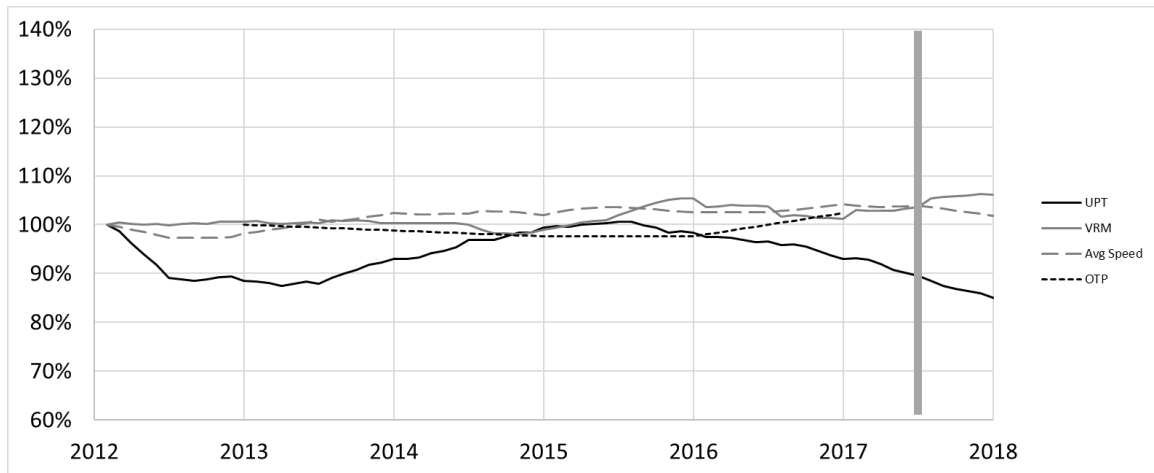


Figure 18 - Maryland Transit Administration Normalized Bus Systemwide Trends

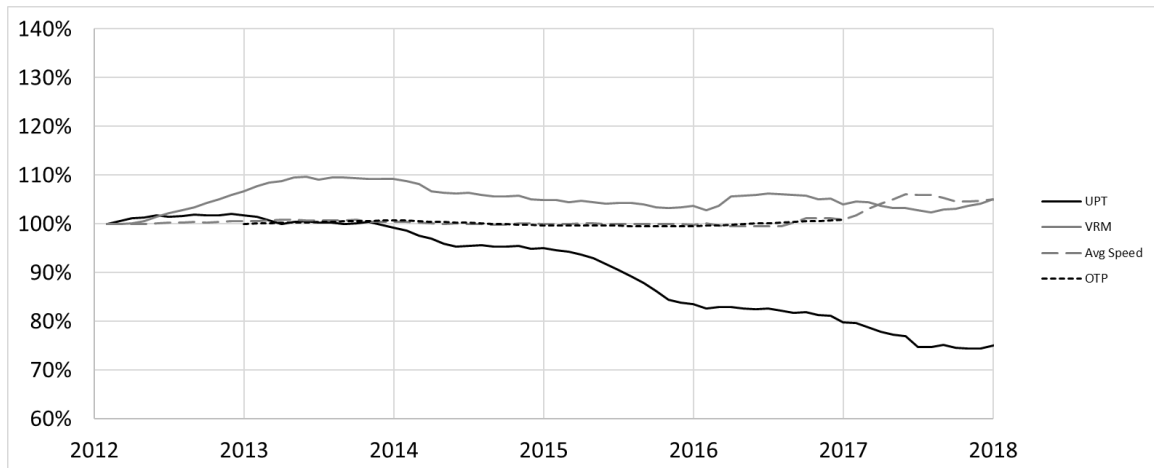


Figure 19 - Maryland Transit Administration Normalized Heavy Rail and Light Rail Systemwide Trends

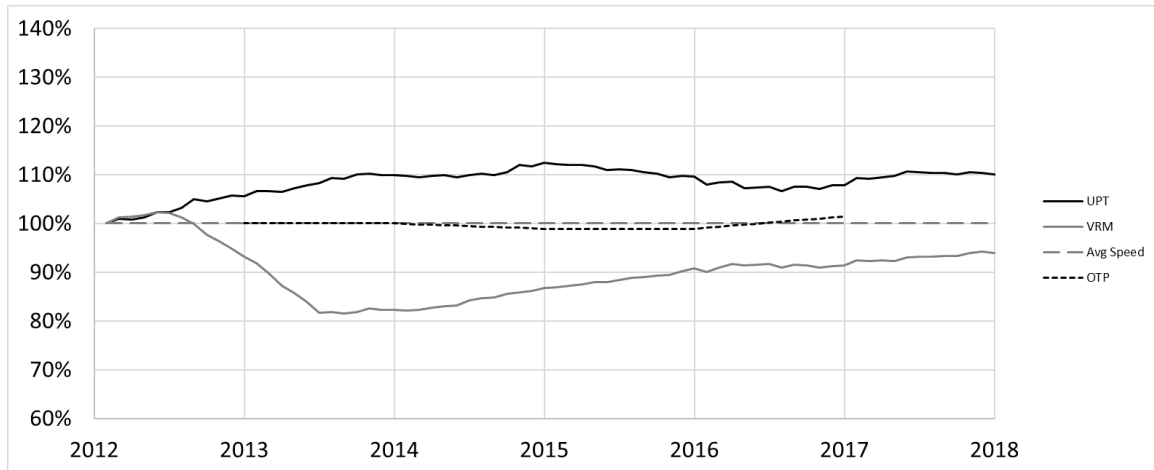


Figure 20 - Maryland Transit Administration Normalized Commuter Rail Systemwide Trends

6.6 Pinellas Suncoast Transit Authority, Tampa, FL

The Pinellas Suncoast Transit Authority (PSTA) is the operator of bus, commuter bus, and demand response services in the St. Petersburg area. Formed in 1984 in the merger of two area transit agencies, the PSTA operates in an interesting position in the greater Tampa-St. Petersburg area. While PSTA serves St. Petersburg and some surrounding areas, a separate agency called Hillsborough Area Regional Transit (HART) serves Tampa and points east. This is despite the downtown areas of Tampa and St. Petersburg lying no more than 15 miles apart. The two systems began cross-honoring fares and allowing free transfers between systems in 2004. PSTA now operates 34 fixed routes across the county.

The agency recently made headlines as the first operator to provide subsidies to TNCs for connecting service to select bus stops. This partnership, which began in 2016, covers the first \$5 of an Uber ride to designated bus stops, expanding their service area

outside of walking distance. Lyft was added soon after, and in 2018, the number of designated stops doubled to 24. This program, called Direct Connect, was the first to integrate TNCs into a local bus system.

An analysis of the trends in Figures 21 and 22 reveals some conflicting results. The TNC partnership start date is indicated on the figures. Bus ridership dropped throughout 2016 and 2017, while service, speed, and OTP remained roughly the same. Demand response ridership, which PSTA uses to categorize these TNC trips, is up nearly 10% since late 2016. In addition, the trend of speed dropping rapidly while VRM increases at a similar rate seems to indicate quite a large increase in Vehicle Revenue Hours. This likely corresponds to a massive increase in the number of “demand response” vehicles on the road at any given time. It appears that while the pilot has grown demand response ridership, buses are not seeing positive results of the pilot. This is perhaps due to the phenomenon of a preference for a one-seat ride. In other words, once passengers are already in the TNC vehicle, they would prefer to take it all the way to their destination than transfer to a bus along the way.

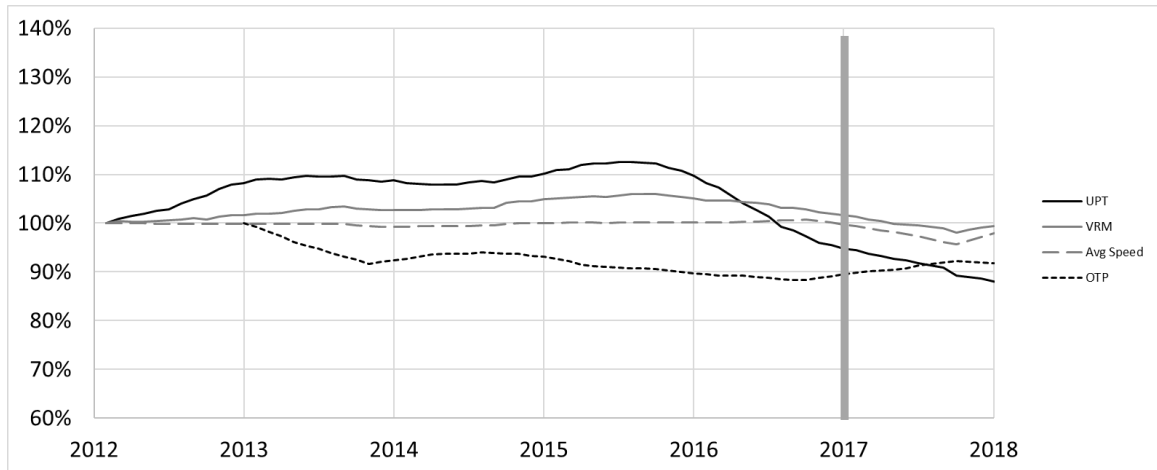


Figure 21 - Pinellas Suncoast Transit Authority Normalized Bus Systemwide Trends

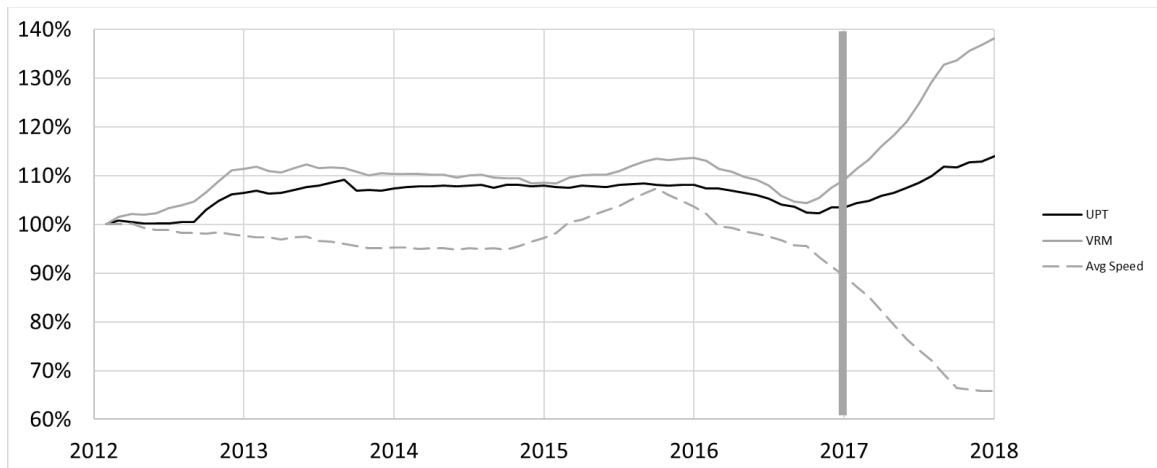


Figure 22 - Pinellas Suncoast Transit Authority Normalized Demand Response Systemwide Trends

6.7 Metro Transit, Minneapolis, MN

Metro Transit operates bus, light rail, and commuter rail services in the Minneapolis-St. Paul metro area. Founded in 1967 providing strictly bus service, the growing Twin Cities region began studying light rail in 1972, but a line would not be

implemented until 2004 with the opening of the Metro Blue Line. In 2009, a commuter rail line opened to the north suburbs. A BRT service began in 2013, and 2014 saw the opening of Metro's current busiest light rail line, the Metro Green Line. In preparation for the opening of the Metro Green Line in June 2014, surrounding bus routes were routed and timed to transfer seamlessly (Metro Transit, 2012). Metro's predictions were that around 40% of Green Line riders would connect to the bus system, and the network needed realignment to best facilitate these connections. The process took around two years to plan and implement. In addition, a new rapid bus service was planned and opened in 2016 with a direct connection to the Green Line (Shieferdecker, 2017). 2015 Green Line ridership was 37,400, nearing Metro's goal of 41,000 yearly rides by 2030. Central Corridor ridership, including green line and surrounding bus routes, nearly doubled between 2013 and 2015 (Metro Transit, 2016).

Trends in bus, light rail, and commuter rail service and ridership since 2012 are outlined below in Figures 23, 24, and 25. Figure 24 has a different scale than the others to accommodate The Green Line opening, which is marked on the figures. Large rail service increases were followed closely by ridership increases. Bus service is also up system-wide. Average speed and OTP have remained generally flat, though the Green Line opening has brought both down for rail service slightly. Unfortunately, Metro only indicates OTP in annual reports, and thus OTP numbers represent an entire year of service.

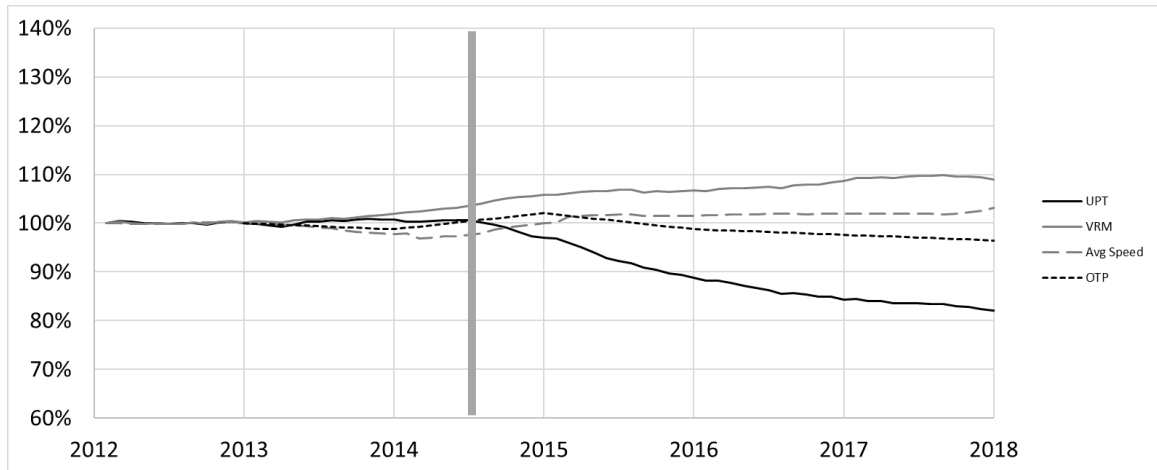


Figure 23 - Metro Transit Normalized Bus Systemwide Trends

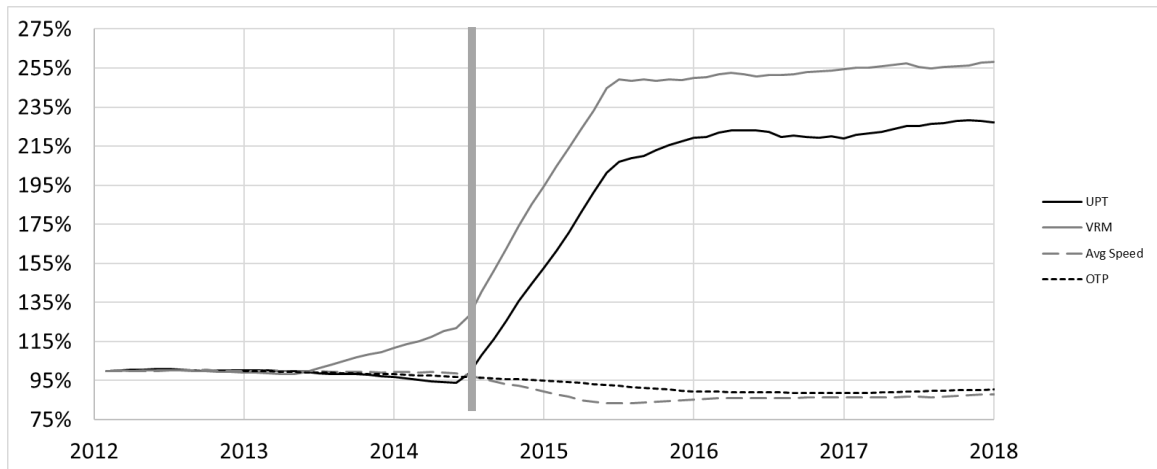


Figure 24 - Metro Transit Normalized Light Rail Systemwide Trends

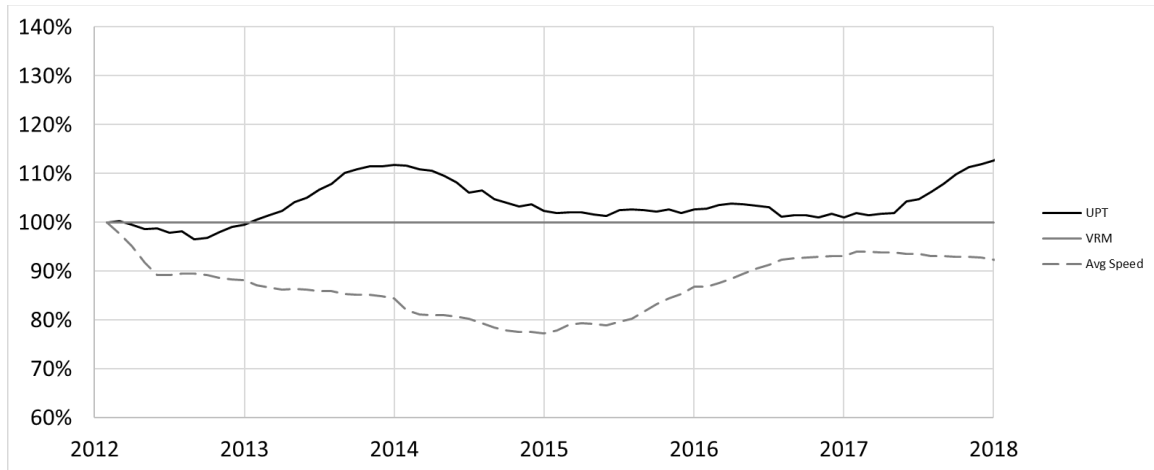


Figure 25 - Metro Transit Normalized Commuter Rail Systemwide Trends

Interviews with planners at Metro Transit provided insight into some strategies being undertaken to combat ridership decline. First, Metro pointed out a trend clearly visible above: that bus ridership decreases at first corresponded to rail ridership increases, as corridors previously served by buses were phased out and replaced with rail service. However, they also observed bus ridership simply continue to drop after rail service was established and stable. They theorized that this is a new reality for transit providers, that additional service may add some ridership, but not nearly as much as it would have decades ago, and the riders are more likely to slip away upon service disruptions. However, Metro did have some good news: a June 2016 rapid bus, the first of its kind in the region, immediately boosted corridor ridership by 30% simply by speeding up bus service. These sorts of corridor- and route-level boosts don't necessarily show up in system-wide analyses, but they have great potential to improve the passenger experience.

6.8 Connect Transit, Bloomington, IL

Connect Transit operates fixed route bus service in the Bloomington-Normal, IL metro area, the smallest of the case studies. The region and its transit ridership is significantly influenced by the presence of Illinois State University. Connect Transit operates 15 fixed routes that converge on two transit centers. Recent trends in ridership and service are shown in Figure 26. No OTP data was available publicly. Ridership since 2012 has followed a remarkable trend, peaking in 2015 at over 35% above 2012 levels, and recently settling near 15% above. This all came with almost no change in service levels and recently declining average speeds. The agency credits their increases in ridership to improvements in technology after gaining a new General Manager in 2011. A redesigned website, mobile bus tracking, a rebranding to Connect Transit, and better customer service all took place in the last several years.

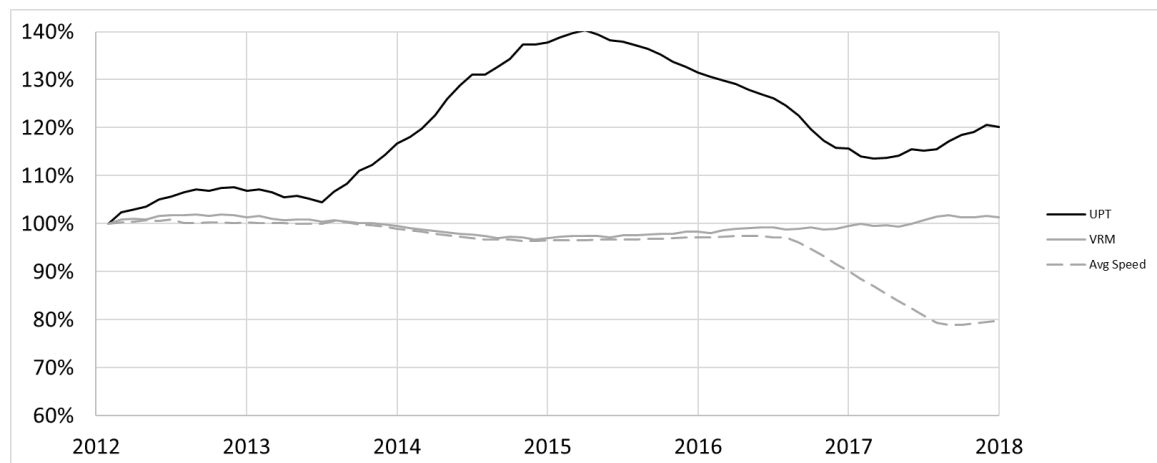


Figure 26 - Connect Transit Normalized Bus Systemwide Trends

6.9 IndyGO, Indianapolis, IN

IndyGO provides fixed route bus service along 31 routes in the Indianapolis region. Struggling with decreasing ridership since the public agency took over operations in 1975, IndyGO has recently undertaken a series of active steps to reverse the trend. Free circulator routes and university-focused routes became popular in the mid 2000s, but quickly fell out of use and were discontinued. Recently, a comprehensive plan for BRT was released, starting with a line opening in 2019. Prior to this, however, the system saw a leap in ridership between 2012 and 2015, followed by steady declines ever since. Service levels have improved, but average speed has dropped to nearly 10% below 2012 levels. These trends are shown in Figure 27. Unfortunately, IndyGO had no publicly available OTP data.

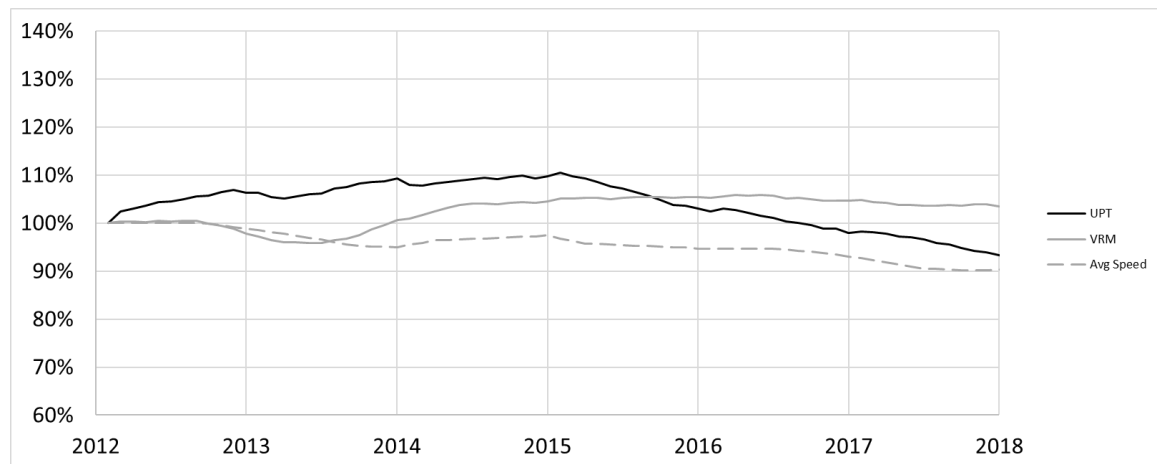


Figure 27 - IndyGO Normalized Bus Systemwide Trends

6.10 Metropolitan Transit Authority of Harris County, Houston, TX

Houston makes for perhaps the most fascinating case study. Discussed heavily in the literature, the Metropolitan Transit Authority of Harris County (known as Metro) runs bus, commuter bus, and light rail service in the Houston metropolitan area. The agency was founded in 1979 to replace a system that was quickly becoming outdated in the rapidly growing Houston region. The first light rail line opened in 2004, ending a 14-year period where Houston was the largest city in the country without a rail system. The most recent rail extension occurred in 2015. Meanwhile, Metro remains primarily a bus system.

In August 2015, Metro redesigned their bus network, increasing high-frequency bus routes, while cutting lower-frequency routes. The system was redesigned for the first time since the 1980s, with some routes unchanged since the 1920s (Lewis, 2015). The logic behind these changes is that Houston's sprawling nature makes downtown-oriented routes only useful for a small number of people. High-frequency gridded routes allow for faster A-to-B travel, even if it requires a transfer. The agency's goal was to simplify bus routes and improve frequency to reach a higher proportion of residents. However, the Houston press reported that low-income neighborhoods lost 12 routes whereas non-low-income neighborhoods gained three (Flynn, 2015).

An analysis of trends for bus and rail modes, shown in Figures 28 and 29, shows some complex results – note that an elongated scale is used on Figure 29 to show the effects of rail openings. Perhaps most obvious is that Houston's bus ridership has remained almost completely flat since a system-wide overnight reimagining, the opening of which is indicated on Figure 28. Steady increases in service levels following the redesign appear to

have little effect on ridership. Additionally, decline in average speed is most likely a product of routes being transitioned to serve denser, more trafficked areas of the city. Rail trends are overwhelmed by the openings of two light rail lines in 2015, indicated on Figure 29. These new lines have steadied out at nearly 300% more service than was provided in 2012, yet ridership sits only 70% above that level.

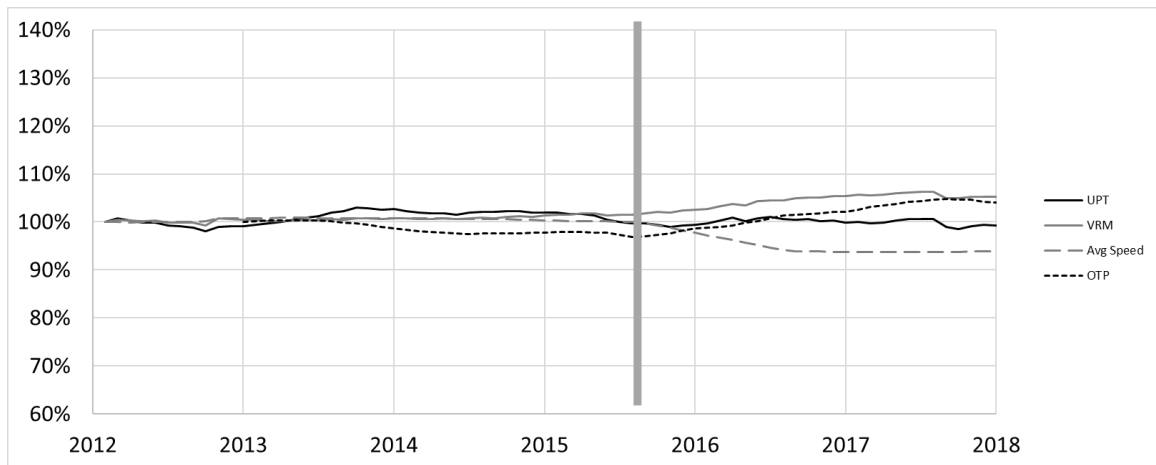


Figure 28 - Houston Metro Normalized Bus Systemwide Trends

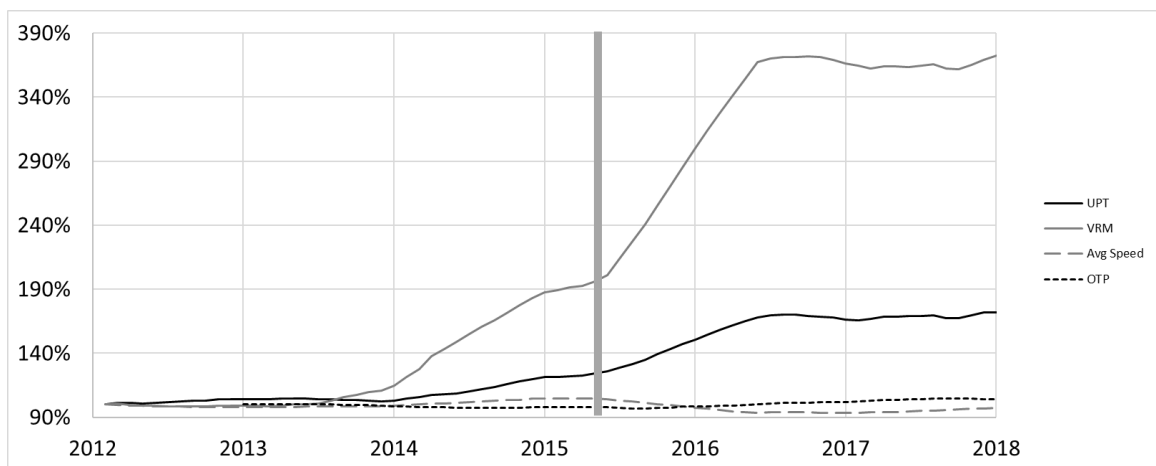


Figure 29 - Houston Metro Normalized Rail Systemwide Trends

An interview with staff at Metro provided some valuable insight into the process and results of the redesign. The Metro board wanted the project rolled out in six months, which severely limited the types of projects Metro could undertake. However, there were several additional parts of the redesign that aided its success. Sidewalks and disability access were improved with a large capital grant, bus stop signage and route maps were upgraded with clearer information, and trip planning apps and text-in next bus information were added. The entire launch was treated as an emergency event like a hurricane, with the call center doubled in size, roaming buses to pick up unknowing would-be passengers at abandoned stops, free fares, and subsidized taxi service for lost riders. This sort of treatment allowed the redesign to go off rather successfully, according to staff.

A key aspect of the redesign was increased weekend service, with nearly all routes running the same service all seven days. This fits in to the Metro staff's idea that it is not always a good idea to attempt to cater to new riders. Instead, making the service better for existing riders, by making buses faster and more reliable, and making them more useful on weekends and off peak, can in turn attract additional ridership by simply getting riders on board more. Reliability was a heavy motivator behind the redesign, though the staff admitted that no study had been done on OTP since then to reveal if their goals had been met. Overall, however, staff did seem satisfied with the results of the redesign, and mentioned a 20% drop in call center usage since the new routes and signage went into effect, a measure of added simplicity to the system that had not existed before.

CHAPTER 7. DISCUSSION AND CONCLUSIONS

Historically, there is a strong consensus in the literature about the connection between service levels and ridership. This relationship appears to hold true for most agencies in the past few decades – this is evidenced by the MARTA peer analysis as well as in interviews and APTA reports. This relationship continues to hold true in general in the case of national statistics and other forms of aggregated data. This relationship certainly holds true where service levels decline, in which case ridership undoubtedly drops along with them, as evidenced by recession-era service cuts in 2008 and 2009. In other words, the picture has been relatively clear since ridership was first recorded that this relationship holds true.

Agency practitioners may argue that due to the directionality of this relationship, service levels are not particularly helpful to determining ridership. While much of the literature declines to comment on the directionality of the relationship, many researchers have arrived at the conclusion that ridership will improve with additional service. Perhaps this is the case for large-scale projects such as rail line openings or a doubling of service, but the conclusion from many practitioners in interviews is that service is added in response to ridership, not the reverse. The situation is clearly nuanced and dependent on a wide variety of environmental factors, but this divergence in thought between groups is interesting nonetheless.

In any case, there is significant evidence that this picture is indeed becoming fuzzier over time. As new mobility options rapidly become available, mode choice becomes more fluid, and it becomes harder to parse exact changes in travel behavior. Services like TNCs,

bike share, and now electric scooters are introducing modes that have the potential to both compete and complement transit. Next, conflicting demographic shifts have been simultaneously occurring. Many central cities are repopulating after decades of neglect, but there is evidence that these new populations are displacing transit captive groups to suburban areas with little transit access. While it becomes increasingly easy to live without a car in many cities, the use of car share and TNCs slowly adds to congestion and degrades transit vehicle speeds in the process. Put simply, there is an incredible amount of change going on, and transit researchers and practitioners do not have a firm grasp on how to handle it.

Now more than ever, new ways of looking at transit data and visualizing ridership are needed. Keeping up with these trends is vital to the continued success of transit in the U.S., and failing to adapt will cause agencies to be left behind. Luckily, key data is increasingly becoming more readily available, comprehensive, and accurate. The national transit database (NTD) has consistently improved its clarity and quantity of data required from agencies and provided to the public every year. With the advent of the American Community Survey (ACS), the U.S. Census Bureau has opened up opportunities to explore year-to-year variation for many geographies. Data from bike-, car-, and scooter-sharing systems can be used to inform both the public and private sector on the types of trips in high demand. All that is required to tap into this abundance of data is the proper preparation of the data for analysis.

My work consisted of a series of data preparation and analysis methods with the goal of informing ridership change. At the agency level, I put together data for an analysis of peer agencies based on ridership. This produced some interesting trends, but it was not

enough to inform any particular ridership causes. I then developed a method for linking NTD data with census data, which can be used for any analysis exploring change in ridership at the core-based statistical area (CBSA) level. In my final analysis, I took a closer look at agencies with particularly interesting trends in ridership, or that have implemented innovative strategies to combat declines.

In the case study analysis, I included on-time performance and speed data to document their trends in an attempt to correlate reliability with ridership. What I found was that the effect of speed and reliability on ridership is weak at best, and a lacking relationship here can probably be explained by a few factors. First, high ridership itself is a cause that can dampen speeds. As dwell times rise and passengers take longer to board and alight the bus under crush loads, buses on busy routes begin to bunch and the problem is exacerbated. This creates the appearance that slow speeds cause high ridership, when the relationship is likely the reverse. Additionally, this creates a situation where more service may be added to a route simply to relieve it, thus, service is added without additional ridership. Buses may also be slowed by their routing taking them through the dense parts of the region. Again, this is a recipe for high ridership, but as intersections become denser and roads more crowded, speeds drop. When there is the appearance that slow speeds and high ridership are correlated, any adverse ridership effects can become masked and negated entirely.

Transportation is entering a fundamentally new era that requires new ways of looking at transit ridership. As cities become more congested, and more mobility options become available, simply adding service may not be enough to get new riders on board. Whether it involves looking at peer agencies, at peer regions, or simply at who is getting it right, agencies must be willing to be innovative when analyzing their trend data.

REFERENCES

- Abubey, Faith (2017). "Community outraged over MARTA bus changes." WXIA, 2 Aug 2017, www.11alive.com/article/news/local/community-outraged-over-marta-bus-changes/85-461375365.
- Altstadt, R. (2018). "Major retailers continue selling paper tickets as Hop Fastpass rollout continues." TriMet News.
- APTA, (2018), Policy Development and Research
- APTA. (2018). "Transit and TNC Partnerships." Retrieved from <https://www.apta.com/resources/mobility/Pages/Transit-and-TNC-Partnerships-.aspx>.
- Austin, D., & Zegras, P. (2012). Taxicabs as public transportation in Boston, Massachusetts. *Transportation Research Record: Journal of the Transportation Research Board*, (2277), 65-74.
- A. W. (2017). "An inglorious return to Austin for Uber and Lyft." *The Economist*.
- BaltimoreLink. (2016). "Route Comparison Maps: Draft 3 BaltimoreLink System: Fall 2016." Retrieved from https://baltimorelink.com/images/library/route_sheets/Route%20Comparison%20Maps.pdf.
- Becker, J., Teal, R., & Mossige, R. (2013). Metropolitan Transit Agency's Experience Operating General-Public Demand-Responsive Transit. *Transportation Research Record: Journal of the Transportation Research Board*, (2352), 136-145.
- Bliss, L. (2016). "How Houston's Bus Network Got Its Groove Back." *CityLab*.
- Bliss, L. (2017). "There's No Transit But Microtransit For This Sprawling Texas City." *CityLab*, 21 Nov 2017, www.citylab.com/transportation/2017/11/a-bus-shunning-texas-towns-big-leap-to-microtransit/546134/.

- Block-Schachter, D., and J. Attanucci (2008). "Employee Transportation Benefits in High Transit Mode Share Areas: University Case Study." *Transportation Research Record: Journal of the Transportation Research Board* 2046: 53-60.
- Boisjoly, G., Grisé, E., Maguire, M., Veillette, M. P., Deboosere, R., Berrebi, E., & El-Geneidy, A. (2018). Invest in the ride: A 14 year longitudinal analysis of the determinants of public transport ridership in 25 North American cities. *Transportation Research Part A*, 116, 434-445.
- Brakewood, C., Macfarlane, G. S., & Watkins, K. (2015). The impact of real-time information on bus ridership in New York City. *Transportation Research Part C: Emerging Technologies*, 53, 59-75.
- Bregman, S. and K. Watkins (2013) *Best Practices for Transportation Agency Use of Social Media*. CRC Press.
- Brown, A. E. (2017). Car-less or car-free? Socioeconomic and mobility differences among zero-car households. *Transport Policy*, 60, 152-159.
- Bueno, P., J. Gomez, J. Peters, and J. Vassallo (2017). "Understanding the effects of transit benefits on employees' travel behavior: Evidence from the New York-New Jersey region." *Transportation Research Part A: Policy and Practice* 99: 1-13.
- Capital Metro. (2017). "Cap Metro Brings Ride-Hailing to Public Transit." Cap Metro Blog. Retrieved from <https://capmetroblog.com/2017/06/07/cap-metro-brings-ride-hailing-to-public-transit/#more-8548>.
- Chesser, J. and Newsom, M. (2012). "A region by many other names." UNC Charlotte Urban Institute.
- City of Boston. (2018, May). "Four-Week, Dedicated Bus Lane Pilot To Begin Monday, May 7, In Roslindale." Retrieved from <https://www.boston.gov/news/four-week-dedicated-bus-lane-pilot-begin-monday-may-7-roslindale>.
- City of Boston. (2018, June). "Permanent Bus Lane To Be Established On Washington Street In Roslindale." Retrieved from <https://www.boston.gov/news/permanent-bus-lane-be-established-washington-street-roslindale>.

- City of Toronto. (2018). "King Street Transit Pilot: April Update." Retrieved from https://www.toronto.ca/wp-content/uploads/2018/05/985c-KSP_Apr-2018-Dashboard-Update_FINAL.pdf.
- Correa, D., Xie, K., & Ozbay, K. (2017). Exploring the Taxi and Uber Demand in New York City: An Empirical Analysis and Spatial Modeling (No. 17-05660).
- Clewlow, R. (2016). "Shared-Use Mobility in the United States: Current Adoption and Potential Impacts on Travel Behavior." TRB Annual Meeting.
- Clewlow, R. R., & Mishra, G. S. (2017). Disruptive transportation: the adoption, utilization, and impacts of ride-hailing in the United States (Vol. 7). Research Report–UCD-ITS-RR-17.
- Davis, J., (2017). VMT hits nominal high, approaches per capita mark. <https://www.enotrans.org/article/vmt-hits-nominal-high-approaches-time-per-capita-mark/> July 5, 2018.<https://www.enotrans.org/article/vmt-hits-nominal-high-approaches-time-per-capita-mark/> July 5, 2018.
- DemandTrans. (2018). "Pace Bus Begins Deploying Next-Generation Demand Response/Microtransit Services." Mass Transit Magazine.
- Dill, J., Schlossberg, M., Ma, L., & Meyer, C. (2013, January). Predicting transit ridership at the stop level: The role of service and urban form. In 92nd annual meeting of the Transportation Research Board, Washington, DC.
- Dong, H., L. Ma, and J. Broach (2016). "Promoting sustainable travel modes for commute tours: A comparison of the effects of home and work locations and employer-provided incentives." *International Journal of Sustainable Transportation* 10.6: 485-494.
- Dovak, P. (2017). "The map for Baltimore's new bus system is positively radiant." Greater Greater Washington.
- Driscoll, R. A., Lehmann, K. R., Polzin, S., & Godfrey, J. (2018). The Effect of Demographic Changes on Transit Ridership Trends, *Transportation Research Record* (No. 18-04556).

Dueker, Kenneth J., James G. Strathman, and Martha J. Bianco. "Strategies to attract auto users to public transportation." (1998).

Ederer, D., Berrebi, S., Diffie, C., Gibbs, T., Carmenate, S., Watkins, K., (2019)
“Comparing Transit Agency Peer Groups Using Cluster Analysis.” Transportation Research Record.

Edwards, D. and K. Watkins (2013). “Comparing Fixed-Route and Demand-Responsive Feeder Transit Systems in Real-World Settings”, Transportation Research Record #2352: 128-135.

Feigon, S., & Murphy, C. (2016). Shared mobility and the transformation of public transit (No. Project J-11, Task 21).

Florida, R (2017). The new urban crisis: How our cities are increasing inequality, deepening segregation, and failing the middle class and what we can do about it. Hachette UK.

Frey, W. H., (2018) US population disperses to suburbs, exurbs, rural areas, and of the country metros, The Avenue. Brookings. <https://www.brookings.edu/blog/the-avenue/2018/03/26/us-population-disperses-to-suburbs-exurbs-rural-areas-and-middle-of-the-country-metros/>

FTA. (2017). “Fiscal Year 2016 Mobility on Demand (MOD) Sandbox Program Projects.”

FTA. (2018). “Mobility on Demand (MOD) Sandbox Program.”

FTA. (2018). “The National Transit Database (NTD).”

Flynn Meagan. (2015, September). No Easy Ride : What Using Metro’s New Bus Network is Like In a Low-Income Community. Houston Press, Retrieved from <https://www.houstonpress.com/news/no-easy-ride-what-using-metros-new-bus-network-is-like-in-a-low-income-community-updated-7727049>

Gallup. (2017), State of the American Workplace.

- Gomez-Ibanez, J. A. (1996). Big-city transit rider snip, deficits, and politics: Avoiding reality in Boston. *Journal of the American Planning Association*, 62(1), 30-50.
- Habib, K. (2017). On the Factors Influencing the Choices of Weekly Telecommuting Frequencies of Post-secondary Students in Toronto. No. 17-01865.
- Hall, J.D., C. Palsson, and J. Price (2018). "Is Uber a Substitute or Complement for Public Transit?"
- Henao, A. and Marshall, W. (2017). A Framework for Understanding the Impacts of Ridesourcing on Transportation, in G. Meyer and S. Shaheen (eds.), *Disrupting Mobility*, Springer International Publishing.
- Hendrickson, C. (1986). A note on trends in transit commuting in the United States relating to employment in the central business district. *Transportation Research Part A: General*, 20(1), 33-37.
- HOP Fastpass. (2018). "Earn Passes and Save as You Ride." Retrieved from <https://myhopcard.com/home/#/save-as-you-ride>.
- Hymon, S. (2017). "Metro plans to reimagine and restructure its vast bus system." *The Source*, 18 May 2017, thesource.metro.net/2017/05/18/metro-plans-to-reimagine-and-restructure-its-vast-bus-system/.
- Iacobucci, J., K. Hovenkotter, and J. Anbinder (2017). "Transit Systems and the Impacts of Shared Mobility." *Disrupting Mobility*. Springer, Cham, 65-76.
- Kain, J. F., & Liu, Z. (1999). Secrets of success: assessing the large increases in transit ridership achieved by Houston and San Diego transit providers. *Transportation Research Part A: Policy and Practice*, 33(7), 601-624.
- Keeley, S. (2016). "Solo Seattle car commuters drop to lowest number ever." *Curbed Seattle*. Retrieved from <https://seattle.curbed.com/2016/9/20/12990478/solo-seattle-car-commuters-lowest-numbers>.
- King County Metro (2017), "Accountability Center." Ridership - Annual Performance Measures - King County Metro Transit, metro.kingcounty.gov/am/reports/annual-measures/ridership.html.

- Kittelton & Associates, Parsons Brinckerhoff, KFH Group. (2013). Transit capacity and quality of service manual. Third Edition, Chapter 5, Quality of Service Methods.
- Kyte, M., Stoner, J., & Cryer, J. (1988). A time-series analysis of public transit ridership in Portland, Oregon, 1971–1982. *Transportation Research Part A: General*, 22(5), 345-359.
- Kohn, H. M. (1999). Factors affecting urban transit ridership. Statistics Canada.
- Laughlin, J. (2017). "SEPTA looks to Texas for ideas for bus route redesign." Philly.com, 11 Sept. 2017, www.philly.com/philly/business/transportation/septa-overhaul-bus-service-houston-model-20170911.html.
- Lewis, P. (2015). "Houston has a shiny, new bus network." *Eno Transportation Weekly*. Retrieved from <https://www.enotrans.org/article/houston-has-a-shiny-new-bus-network/>.
- Liu, Z. (1993). Determinants of transit ridership analysis of post WWII trends and evaluation of alternative networks.
- Manville, M., Taylor, B. D., and Blumenberg, E. (2018). "Falling Transit Ridership: California and Southern California." Southern California Association of Governments, http://www.scag.ca.gov/Documents/ITS_SCAG_Transit_Ridership.pdf
- Marshall, A. (2016). "Kansas City Is Embarking on a Great Microtransit Experiment." CityLab.
- Marshall, A. (2017). "How A Failed Experiment Could Still Be The Future Of Public Transit." *Wired*.
- Martin, E. and S. Shaheen (2011). "The impact of carsharing on public transit and non-motorized travel: an exploration of North American carsharing survey data." *Energies* 4.11: 2094-2114.
- Maryland Transit Administration. (2017). "Network Redesign." Retrieved from <https://baltimorelink.com/service/network-redesign>.

Metro Transit. (2012). “Central Corridor Transit Service Study Recommendation Plan – November 2012.”

Metro Transit. (2014). “Central Corridor Transit Service Study Final Plan Report.” Retrieved from <https://www.metrotransit.org/Data/Sites/1/media/pdfs/central/finalcctransitstudyreportupdate.pdf>.

Metro Transit. (2016). “Metro Transit ridership tops 85.8 million in 2015.”

Mills, T., and M. Steele (2017). In Portland, Economic Displacement May Be a Driver of Ridership Loss. Transit Center, 14 Nov. 2017, <http://transitcenter.org/2017/11/14/in-portland-economic-displacement-may-be-a-driver-of-transit-ridership-loss/>

NACTO. (2015). “Case Study: Metro Bus Network Redesign, Houston.” Transit Street Design Guide.

O’Neil, K. (2013). “3 reasons why the CTA is switching to Ventra card payment system.” Chicago Now.

Owen, A., & Levinson, D. M. (2015). Modeling the commute mode share of transit using continuous accessibility to jobs. Transportation Research Part A: Policy and Practice, 74, 110-122.

Parsons Brinckerhoff Inc., (2016). Comprehensive Operations Analysis. Atlanta, GA., Task Order No. 2014-LRSRP-2.

Polzin, S. (2016), Implications to Public Transportation of Emerging Technologies, National Center for Transit Research, <https://www.nctr.usf.edu/wp-content/uploads/2016/11/Implications-for-Public-Transit-of-Emerging-Technologies-11-1-16.pdf>.

Powers, M (2017). “Metro is mulling a major redesign of the bus system. But first, officials need to figure out why people aren't riding.” The Washington Post, WP Company, 30 Dec. 2017, www.washingtonpost.com/local/trafficandcommuting/metro-is-mulling-a-major-redesign-of-the-bus-system-but-first-officials-need-to-figure-out-why-people-arent-riding/2017/12/30/

- Pritchard, C. (2017). "Capital Metro takes its bus network realignment to the riders." Austin Monitor, 19 Sept. 2017, www.austinmonitor.com/stories/2017/09/capital-metro-takes-bus-network-realignment-riders
- PSTA. (2016). "PSTA Expands Transit Partnership With Uber, Lyft Across Pinellas County"
- Pushkarev, B., Zupan, J. M., (1977). Public Transportation and Land Use Policy.
- Qiu, F., Shen, J., Zhang, X., & An, C. (2015). Demi-flexible operating policies to promote the performance of public transit in low-demand areas. *Transportation Research Part A: Policy and Practice*, 80, 215-230.
- Rayle, L., Dai, D., Chan, N., Cervero, R., Shaheen, S. (2016). Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco, *Transport Policy*, Volume 45, Pages 168-178, ISSN 0967-070X, <http://dx.doi.org/10.1016/j.tranpol.2015.10.004>.
- Sale, J. (1976). Increasing transit ridership: the experience of seven cities (No. UMTA-UPP-S-76-1).
- Schaller, B. (2018). "The New Automobility: Lyft, Uber and the Future of American Cities." Schaller Consulting.
- Schmitt, A. (2017). "Dallas Council Members Say Bus Network Overhaul Can't Wait." Streetsblog USA, 10 July 2017, usa.streetsblog.org/2017/07/10/dallas-council-members-say-bus-network-overhaul-cant-wait/.
- Schmitt, A. (2017). "Transit Ridership Falling Everywhere - But Not in Cities with Redesigned Bus Networks." Streetsblog USA, 27 Feb. 2017, usa.streetsblog.org/2017/02/24/transit-ridership-falling-everywhere-but-not-in-cities-with-redesigned-bus-networks/.
- Schmitt A. (a) (2018, 23 MARCH). Only A Few Cities Are Growing in Transit Ridership: Here is What They Are Doing Right. Streetsblog USA, <https://usa.streetsblog.org/2018/03/23/only-a-few-american-cities-are-growing-transit-ridership-heres-what-theyre-doing-right/>

- Schmitt A. (b) (2018, 12 SEPTEMBER). Indianapolis' Transit Investment Is Starting to Pay Off. StreetsBlog USA, <https://usa.streetsblog.org/2018/09/12/indianapoliss-transit-investment-is-starting-to-pay-off/>
- SFCTA, (2017), TNCs Today: A Profile of San Francisco Transportation Network Company Activity, Final Report, https://www.sfcta.org/sites/default/files/content/Planning/TNCs/TNCs_Today_112917.pdf
- Shaheen, S., A. Cohen, and M. Chung (2009). "North American carsharing: 10-year retrospective." *Transportation Research Record: Journal of the Transportation Research Board* 2110: 35-44.
- Shaheen, S., Stocker, A., Lazarus, J., and Bhattacharyya, A. (2016). "RideKC: Bridj Pilot Evaluation: Impact, Operational, and Institutional Analysis." *Transportation Sustainability Research Center (TSRC)*, UC Berkeley.
- Shieferdecker, A. (2017). "Three Complaints and Three Ideas for Minneapolis-St. Paul's Future METRO System." *Streets MN*. Retrieved from <https://streets.mn/2017/11/20/three-complaints-and-three-ideas-for-minneapolis-st-pauls-future-metro-system/>
- Shockley, D., Salinas, J., and Taylor, B. D. (2015). *Making Headways: An Analysis of Smart Cards and Bus Dwell Time in Los Angeles*. UCLA ITS.
- Silver, N. and Fischer-Baum, R. (2015). "Public Transit Should Be Uber's New Best Friend." *FiveThirtyEight*. Retrieved from <https://fivethirtyeight.com/features/public-transit-should-be-ubers-new-best-friend/>
- Sioui, L., C. Morency, and M. Trépanier (2013). "How carsharing affects the travel behavior of households: a case study of Montréal, Canada." *International Journal of Sustainable Transportation* 7.1: 52-69.
- Sisson, P. (2018). "Microtransit: How cities are, and aren't, adapting transit technology." *Curbed*.
- Small, A. (2017). "How Seattle Bucked a National Trend and Got More People to Ride the Bus." *CityLab*, 17 Oct. 2017, www.citylab.com/transportation/2017/10/how-seattle-bucked-a-national-trend-and-got-more-people-to-ride-the-bus/542958/.

- Spielman, F. (2017). "City working on Ventra-Divvy integration." Chicago Sun-Times.
- Spillar, R. J., & Rutherford, G. S. (1990). The effects of population density and income on per capita transit ridership in western American cities. In INSTITUTE OF TRANSPORTATION ENGINEERS MEETING.
- Spurr, B. (2018). "Spending on King St. up since streetcar pilot began." The Star.
- Suel, Esra, and John W. Polak. "Incorporating online shopping into travel demand modelling: challenges, progress, and opportunities." *Transport Reviews* 38.5 (2018): 576-601.
- Taylor, B. D., Miller, D., Iseki, H., & Fink, C. (2009). Nature and/or nurture? Analyzing the determinants of transit ridership across US urbanized areas. *Transportation Research Part A: Policy and Practice*, 43(1), 60-77.
- Taylor, B. D., and Fink, C. (2013) Explaining transit ridership: What has the evidence shown? *Transportation Letters*. 5:15-26.
- TCRP Report 95, (2004), *Traveler Response to Transportation System Changes Handbook*, Third Edition.
- Transit Center, (2016), Private mobility, public interest, <http://transitcenter.org/publications/private-mobility-public-interest/#summary-of-key-findings>
- Transit Center (2018, 29 June). Lessons on Ridership From the National Literature. <http://transitcenter.org/2018/01/29/lessons-on-ridership-from-the-national-literature/>
- TriMet. (2018). "Paying Fare Using Paper Tickets and Passes."
- van Lierop, D., & El-Geneidy, A. (2017). A new market segmentation approach: evidence from two Canadian cities. *Journal of Public Transportation*, 20(1), 2.
- Ventra. (2018). "Introducing the Ventra App." Retrieved from <https://www.ventrachicago.com/app/>.

- Vock, D. (2017). "Bus Network Redesigns Are the Hottest Trend in Transit." Government Technology: State & Local Government News Articles, www.govtech.com/fs/Bus-Network-Redesigns-are-the-Hottest-Trend-in-Transit.html.
- VTA. (2016). VTA FLEX: Overview. Retrieved from <http://www.vta.org/getting-around/vta-flex>.
- Walker, J. (2012). Human transit: How clearer thinking about public transit can enrich our communities and our lives. Island Press.
- Wang, F., & Ross, C. L. (2017). New Potential for Multimodal Connection: Exploring the Relationship Between Taxi Trips and Transit in New York City (No. 17-05132).
- Westervelt, M., Huang, E., Schank, J., Borgman, N., Fuhrer, T. Peppard, C., and Narula-Woods, R. (2018). "UpRouted: Exploring Microtransit in the United States." Eno Center for Transportation.
- Yang, C., & Gonzales, E. (2014). Modeling taxi trip demand by time of day in New York City. Transportation Research Record: Journal of the Transportation Research Board, (2429), 110-120.
- Yang, C., Morgul, E., Gonzales, E., & Ozbay, K. (2014). Comparison of mode cost by time of day for nondriving airport trips to and from New York City's Pennsylvania Station. Transportation Research Record: Journal of the Transportation Research Board, (2449), 34-44.
- Zipcar. (2017). "Zipcar and Miami-Dade County partner to add car-sharing vehicles along metrorail lines."
- Zipcar. (2018). "Zipcar and the Maryland Department of Transportation, Maryland Transit Administration partner to launch car-sharing vehicles at transit stations."